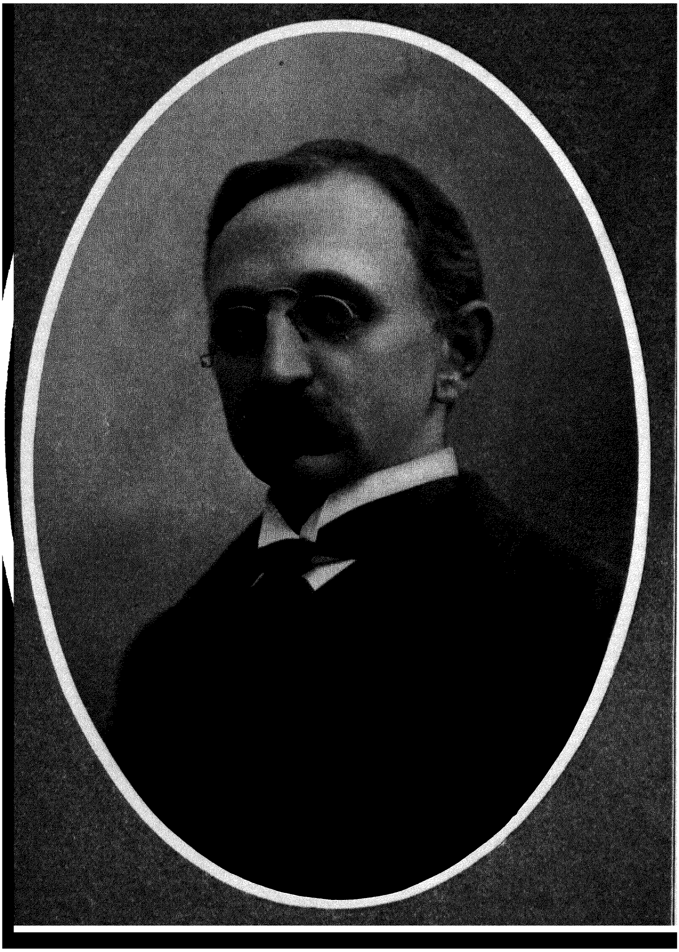

# ENGINEERING CONTRACTS AND SPECIFICATIONS

INCLUDING

A BRIEF SYNOPSIS OF THE LAW OF CONTRACTS AND ILLUSTRATIVE EXAMPLES OF THE GENERAL AND TECHNICAL CLAUSES OF VARIOUS KINDS OF ENGINEERING SPECIFICATIONS

DESIGNED FOR THE USE OF STUDENTS, ENGINEERS AND CONTRACTORS

BY

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UNIVERSITY OF WISCONSIN

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# PREFACE.

The leading American Engineering Schools have long needed a text-book on the subject of the Law of Contracts and Engineering Specifications. In the absence of any such text, this department of engineering practice has received scant and meagre treatment at the hands of these schools. This work has been written primarily to serve this purpose. After it was completed, however, it seemed to the author it might prove of value to the profession at large and also to contractors, especially those portions of it treating of the Law of Contracts and of the General Clauses in Specifications.

While the author makes no pretension to a knowledge of law, he has read the standard authors on this subject, and has for some years lectured on contracts and specifications to his engineering students. He has tried to follow strictly the recognized authorities in all he has said in this work, and while he thinks his synopsis may serve as a good general guide to the fundamental principles of the subject, he recommends that the reader refer all important particular cases to his attorney, or else consult the standard works themselves. If a single volume is desired containing a general review of the Law of Contracts, the layman can not do better than obtain that of John D. Lawson, of the Law Department of the Missouri State University. Another similar, and perhaps better work for the young lawyer, is that of J. P. Bishop; while Parson's three-volume work is the recognized standard authority for the lawyer.

Since this work is designed only for laymen, however, the author may well quote the maxim that "the man who is his own lawyer has a fool for a client." The brief synopsis of the law herein given, therefore, is not intended to remove the necessity of consulting a lawyer on all important matters, but only to enable one to steer clear of some of the legal pitfalls which lie in the way of every business man and especially of engineers.

Since custom has laid on engineers and architects the duty of writing specifications and contracts, it is well for them to know something of the legal ground they are forced to traverse. The first part of this work is intended, therefore, to serve as a cautionary warning against legal entanglements, rather than as a counselor or guide through such difficulties. The synopsis of the Law of Contracts as here given has been revised by a very competent legal authority, and the author is indebted to him for many valuable suggestions and corrections. It probably will not mislead one into trouble, though it may not always point the way out.

The author also wishes to acknowledge his indebtedness to the many prominent engineers who have kindly sent him copies of their latest specifications for use in this work, and he has acknowledged this debt in the body of the book by appending to each quotation the initials of the person quoted. A key to these initials is given on page IX.

The illustrative examples of engineering specifications given in Part III are selected so as to cover a wide field with as little repetition as possible. They are not given to be blindly copied, but rather as illustrating a good method of treating the subject, and to serve as patterns as to manner as well as to matter. As the best engineers seldom copy their own specifications or use them unchanged a second time, much less can one safely copy

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# PREFACE TO THIRD EDITION.

In this edition a general revision of Part IV has been made, in addition to minor changes in the other portions of the book. Several complete specifications have been entirely changed, or replaced, and many new ones have been added. These latter include Specifications on Riveted Steel Water Pipe; Wooden Stave Water Pipe; Wrought Iron Chains; Railroad Concrete Work; Railway Road-beds; Levees; Steel Highway Bridges and Viaducts; Steel Railroad Bridges and Viaducts; Preservation of Railroad Cross-ties; Filter Gravel and Sand; Specifications and Contract for Architect's Services; and the general specifications for testing hydraulic cements, adopted by the U. S. Engr. Corps. Besides these, two new appendices are given on The Engineer as an Expert Witness, and the Standard Specifications for Iron and Steel proposed by the American Committee of the International Association for Testing Materials.

The three great works on Engineering Contracts and Specifications are those by Mr. John Casson Wait, M. C. E., LL. B., namely: Engineering and Architectural Jurisprudence; The Law of Operations Preliminary to Construction in Engineering and Architecture; and The Law of Contracts; all these are published by John Wiley & Sons. These books are excellent texts for the lawyer, as full citations of cases are given. Mr. Wait is now Asst. Corporation Counsel for the City of New York.

The book has been enlarged by these additions by 114 pages, and the author hopes it may thus have an increased usefulness to the members of the Engineering profession. J. B. J.

Madison, Wis., June, 1902.

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# ENGINEERING CONTRACTS AND SPECIFICATIONS.

## PART I.

### Brief Synopsis of such portions of the Law of Contracts as bear on the carrying out of Engineering or Architectural Construction.

1. **Introductory.** The Law of Contracts is said to be as simple and as readily comprehended by the layman as any department of the law. Two standard single volume works on the law of contracts are those of Bishop and of Lawson,[1] to which the reader is referred for a more complete treatment of the subject, and from which the following synopsis has been principally derived. In this synopsis only such rules and principles are incorporated as may be profitably presented to undergraduate students in our leading engineering schools. The practicing engineer or architect may also find them valuable, however, as furnishing to him certain guiding principles, the recognition of which will frequently enable him to avoid legal complications and inherent weaknesses in the drawing of specifications and other documents pertaining to contracts. This work is intended to emphasize the necessity of consulting competent legal authority in all important matters rather than to enable one to dispense with such reliance.

2. **Essential Elements of a Legal Contract.** A contract is a promise to do or to refrain from doing some act which the

[1] Engineers and Contractors will find Prof. Wait's work, described on page vii, of most value for all cases arising in their practice.

law will enforce. The law will not enforce an agreement unless the following essentials are fulfilled:

*First.* The parties must be *competent* to make the agreement.

*Second.* The subject-matter must be *lawful.*

*Third.* The parties must have mutually *assented* or *agreed* to the conditions named, or they must have been of the same mind and intention concerning the subject-matter.

*Fourth.* Except in the case of sealed contracts there must be a *valuable consideration.*

The four essentials of a legal contract, therefore, may be grouped under the four words, Competency, Legality, Agreement, and Consideration.

3. **Two General Classes of Contracts.** There are in general two kinds of contracts, namely: contracts made under seal, called *sealed* contracts or *specialties* (see Art. 28), and simple written or oral agreements unaccompanied with the formality of a seal, called *parol* contracts.

A sealed contract is a written agreement signed by the parties, the signatures having appended to them what is commonly known as a seal. Formerly a seal consisted of "An impression on wax, or paper, or some other tenacious substance capable of being impressed." Now, however, an impression of a seal on the paper itself is commonly construed as a proper seal, and in many states by statute a mere scroll enclosing the word "seal" made opposite the name of the signer is sufficient.

Engineering contracts are often executed under seal, though preferably not, while the bond which holds the sureties for the faithful performance of the work by the contractor must be under seal. This is necessary because the agreement of the bondsmen to become responsible for the faithful performance of the contract by the contractor is not usualiy supported by a valuable consideration.

The principal difference between a sealed contract and one not under seal is that in the former case a valuable consideration is not required to support the agreement, while in the latter

case the contract is invalid unless such a consideration can be shown to exist.[1]

The affixing of a seal to a signature implies a special care and deliberation on the part of the signer, more than can be assumed in the case of a simple signature. It is for this reason that a consideration is not required to support a sealed contract.

The mere existence on the document of a printed scroll or word "seal" on the lines provided for signatures does not constitute a sealed document unless these words or scrolls were so intended by the signers.

---

## COMPETENCY.

4. **Competency of Individuals.** A sane person who has attained his majority is competent to make any legal agreement or contract. The disabilities of married women in the matter of contracts are numerous, but will not here be entered upon. Neither wi'l any reference be made to those disabilities pertaining to aliens, convicts, infants, insane persons, and drunkards.

5. **Competency in Governmental Relations.** The national or any state government may become a party to a contract, and such government may sue on its contracts and enforce them, but the converse of this is not true. *Neither the United States nor any state can be sued without its consent.*[2] The only remedy for a person who seeks the enforcement of a contract with such a government is an appeal to congress or to the state legislature. Many of the states of the south have repudiated their contracts in the matter of state bonds, issued during the periods of reconstruction, and the bondholders have no remedy. Neither are public officers who negotiate contracts on the part of the state personally liable on contracts made in their own names when these are signed in their official capacities. This

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[1] See subject of Consideration, Art. 24.

[2] The state may consent to be a party to a suit in order to have the rights of the parties passed upon by the courts.

freedom from all legal necessity to carry out its contracts is an essential element of sovereignty, and applies to kings and other more or less absolute rulers in their official relations.

All public corporate governments subordinate to that of the state, as of the county, or township, or village, or city, can be sued upon their contracts, and such contracts enforced whenever these lie within their legal corporate powers.[1] Thus a county, or town, or city, can not repudiate its legal obligations, as the state has the privilege of doing, but these obligations can be enforced through the agency of the courts. For instance, if a county organization should wish to repudiate a particular issue of bonds, which have been issued and sold because of some real or fancied grievance connected therewith, and if the county commissioners who represent the county in its corporate capacity should refuse to levy taxes for the payment of the interest or principal, the courts could order them to do so, and if they should refuse they could be fined and imprisoned for contempt. In some cases city charters have been repealed by the state legislature and the city changed into a "taxing district" in order to more readily enforce orders of the courts, in requiring them to fulfill the terms of some legal contract or obligation.

**6. Competency of Semi-Public and Private Corporations.** A corporation has no powers for entering into or performing contracts beyond those given it by the state in its charter.[1] Its capacity for transacting business, however, is not limited to the specific privileges granted in its charter, but is of necessity extended by implication to include such other powers as may be necessary for the complete consummation of its specific purposes. For instance, if a corporation requires the use of certain real estate for the transaction of its business, it can evidently buy and sell such property when this is intended for its own uses. It may also borrow money and issue therefor various kinds of obligations, and, in fact, it may make any contract

[1] All legal formalities must, however, have been complied with, and persons contracting with such corporations must assure themselves that this has been done, otherwise they can not recover, as the officers of such corporations, are not personally liable

which it is lawful for an individual to make, provided such contract relates to a subject which is within the sphere of its operations.

When a contract or agreement on the part of a corporation does not fall within its express or implied powers, it is termed *ultra vires*, and such contracts can not be enforced. The official acts of the officers or agents of a corporation bind it much the same as such acts would bind an individual when made in a private capacity, and this applies both to oral and to written agreements, unless the corporation charter specifically requires certain kinds of agreements to be in writing.

7. **Contracts by Agents.**[1] A contract by an agent is not valid unless the principal is himself competent to enter into a contract. On the other hand, a contract by an agent is valid, provided the principal is competent, even though the agent be incompetent to enter into a contract as a principal. Thus a minor may be a competent agent, but not a competent principal. The agent, however, must have no adverse interest from that of his principal under the contract negotiated. For instance, he must not be interested on both sides of the agreement, if these interests are supposed to be adverse.

The legality of the acts of an agent is similar to the legality of the acts of a corporation. As a corporation receives its authority for the transaction of a particular kind of business from the state, and its capacity in the formation of contracts is limited thereby to the express and implied powers under its charter, so an agent receives his authority from his principal, his legal acts are limited to the scope of the authority conferred upon him by his principal, and, as in the case of a corporation, he will be justified in the law in the making of any contract, as agent, which may prove to be necessary or essential to the carrying out of his more specific instructions, or for the transaction of the business for which he has received special authority.

Unlike a corporation, however, an agent may exceed both

[1] An engineer or architect is the agent of the owner (person or corporation), and as such has the express powers given him in the contract itself or in his agreement with his employer, and also many customary implied powers.

his express and implied authority in the making of a contract, and yet this contract will become binding on the ratification of it by his principal. This ratification may also be either expressed or implied, an implied ratification consisting of a failure to object or protest or to annul the contract on learning of its existence, or of acting under it as though consent had been given.

A ratification, whether express or implied, of the acts of an agent operates always so as to include the whole of the agent's acts pertaining to the particular transaction in question, and can not operate for the acceptance of a part, and the rejection of other parts. By adopting a part, the principal is bound by the whole. If it appear, however, that the express or implied ratification was due to a mistake of fact, the principal may repudiate the action of the agent on learning of the facts.

If the agent wishes to avoid personal responsibility in the entering into a contract, it must be understood by the other party that he is acting as an agent, and not in his own behalf. He may, however, enter into contract in his own name, not as an agent, when in fact he is the agent of another party. In this case, however, the other party to the contract on learning of the principal, has his option to enforce the contract against the agent or against the principal as he may choose. In all cases of contracts with agents the other party to the contract must know of the agent's authority aside from the agent's own testimony in the case, as this latter is not received as evidence of the fact. Whatever the agent's pretended authority may be, if it should prove that he has exceeded both his express and implied authorization, the principal is at liberty to repudiate his acts, and the other party to the contract has no remedy except against the agent himself. The agent's authcrity is evidenced, however, by the usual and customary transactions of such agent which have been accepted by his principal, and which have become known to the other party in a proposed new contract. Therefore as to third persons the authority of the agent may be implied from previous performances of similar

acts which have come to the knowledge and received the consent of the principal.

In the case of sub-agency, or of the appointment of an agent by an agent, such authorization must proceed originally from the principal, or be afterwards ratified by him before the principal can be bound by the acts of the sub-agent.

In order that an agent may relieve himself from responsibility in the signing of a contract, the document must reveal, either in its body or in the signature, who the principal is; a mere signing of a contract by a person as "agent" will not relieve the party so signing from personal responsibility unless the document does reveal the principal.

If an agent enters into contract in a matter beyond his express and implied authorization, he becomes personally liable to the third party, unless he reveal to such party, at the time of the signing of the contract, the exact relation between himself and his principal in such a way that this third party becomes aware of the dubiousness of the agent's authority. In this case the principal may repudiate the act of his agent and the third party will not be able to hold either principal or agent to the contract. If, however, the agent does not disclose his exact relations with his principal, and assumes authority beyond his authorization, he does become personally liable for such damage as may result from failure of performance on the part of his principal.

The principal is also liable for all the frauds, deceits, and negligent acts of his agent so long as these pertain to the business he is authorized to perform. In this case, of course, the agent himself is liable both to his principal and to any third party. While if such fraud or deceit or negligent act pertains to matters outside the scope of his authority, the agent alone is liable.

Acts of an agent continue to be binding upon the principal as to third persons, even if the agent's authority has been revoked and the agency ended, until such termination of the agency comes to the knowledge of such third person. This

applies to all kinds of continuous agencies, but does not apply, of course, to an agency for the performance of a particular act.

The death of the principal always acts to terminate the agency, which termination occurs at the instant of the death of the principal. This nullifies even such acts of the agent after the death of his principal as may have occurred before such death came to the knowledge of the agent; but when the agent enters into contracts for his principal after the decease of the latter, with or without the knowledge of such decease, the contract is void as against the estate of the principal, and, generally speaking, as against the agent himself, and the third party is without remedy. In this case no notice of the termination of the agency is required. In a few states, however, the rule has been adopted that the *bona fide* acts of the agent after the death of his principal and before he becomes aware of the fact, and which do not require the principal's signature are valid in favor of third parties.

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## LEGALITY OF THE AGREEMENT.

**8. Kinds of Illegal Subject-Matter.** No contract can be enforced in the courts which involves an agreement to perform an act which is (*a*) forbidden by statutory law, or (*b*) is contrary to the rules of common law, or (*c*) which is opposed to public policy.

**9. Contracts in Breach of Statute Law.** This subject will not here be entered upon at length. It may be said, in short, that all acts which are expressly prohibited by statute law, or all acts for which specific penalties are attached in national, state, or municipal laws, if made the subject of a contract, such contract can not be enforced. Without here mentioning the acts which would be criminal or immoral, it may be well to call attention to a certain class of contracts which can not be en-

forced at law because the plaintiff in the suit has no legal standing in court. Thus where the state statute requires a diploma or license for the practice of medicine or surgery, or a license to act as attorney at law, or as a surveyor, or as an engineer, a person not having such legal authorization can not collect in the courts the price of his professional fees.

Under this head also fall agreements to pay usurious interest, which in some states involves the forfeiture of the entire interest, and in a few states the entire contract becomes void even to the sacrifice of the principal.

In most states all kinds of wagers are declared unlawful by statute and can not be collected.

While all contracts for fire or life insurance are in a certain sense wagers, they are valid and lawful when the person for whose benefit the insurance is made can be shown to have a suitable interest in the property or person insured.

In all states where Sunday labor, with the exception of "works of necessity and charity," is prohibited, contracts made on Sunday are illegal and can not be enforced.

Where contracts in breach of statute law have been fully executed, in other words, where the act has been done and the compensation received, the law will not recognize such transactions for the purpose of annulling them. Thus, in the case of a wager which has been paid, the law will not enforce the return of the money.

**10. Immoral Acts.** The courts will not enforce an agreement, the object of which is forbidden either by statute or by common law, or which in law may be regarded as immoral or wrong. Such agreements might relate to such subjects as the commission of crime; all kinds of frauds upon creditors, either by way of fraudulent assignments, or by way of agreements with certain creditors to the disadvantage of others; all kinds of transactions under false pretenses, as the selling of articles under false labels; fraudulent conveyance of real estate to defraud creditors; changes in contracts after they have been signed, either by one party without the consent of the other,

or by the two principals without the consent of the sureties; all acts of officers of corporations in their official capacity, in furtherance of their private ends; fictitious bidding at auctions for the purpose of raising the bids of *bona fide* purchasers; collusion between the auctioneer and private individuals to defraud owner, and the like.

The particular class of illegal acts in this category which has especial interest to engineers, is that referring to changes in contracts agreed to by the principals without the consent of the sureties or bondsmen. In all such cases if the changes are material, that is to say, if they are such as may be said to have a money value, then if these changes be made without the consent of the surety, such surety can no longer be held for any damage resulting from failure of his principal to fulfill his agreement.[1] Since such changes are almost always made in all contracts after they are signed and before the work is fully executed, and since it is very common to neglect to obtain the consent of the sureties when making all such changes, these sureties or bondsmen are nearly always relieved from liability in the manner here indicated. Furthermore, if such sureties are consulted in regard to the proposed changes and they should not choose to give their consent, then if they are still to be held for the fulfillment of the contract their consent to such changes must be purchased, the same as must be done with the principal himself as provided for in the specifications or contract. Because of this common oversight and the resulting relief of these sureties, or of their opposition to allowing changes to be made in case they are consulted, it is becoming customary to provide some other kind of guarantee of fulfillment, other than that of personal sureties.

11. **Contracts Opposed to Public Policy.** These contracts may relate to all such acts as may be shown to be detrimental to the public welfare. Such as acts which would tend to injure the public service, or to obstruct the course of justice, or to en-

[1] This does not apply to contracts containing a provision for changes under given conditions, provided these conditions are strictly complied with and the changes are not too radical.

courage litigation, or as have an immoral tendency, or as will restrain the freedom of trade, or as will diminish the security of property and life. As such contracts in general have no immediate bearing upon the work of engineers they will not be further enlarged upon here. There is, however, a class of agreements commonly entered into by the principals to an engineering contract which are often construed in the courts as against the public policy, which will be discussed in the following article.

12. **Agreements Which Refer to Arbitration.** The following discussion of this subject is taken bodily from Lawson on Contracts, being Article 318 of that work:

"An agreement that matters which have arisen or may arise between the parties shall be referred to an arbitrator or arbitrators is not binding and either party may have recourse to the courts notwithstanding it. The reason of the rule is by some traced to the jealousy of the courts and a desire to repress any attempt to encroach on the exclusiveness of their jurisdiction, and by others to an aversion on the part of the courts from reason of public policy to sanction contracts by which the protection which the law affords the citizen is renounced.

"But when a contract contains a condition which provides that disputes arising out of it shall be referred to arbitration, the validity of such a condition depends upon rather a fine distinction. Where the *amount of damage sustained by a breach* of the contract is to be ascertained by specified arbitration before any right of action arises, the condition is good; but where all matters in dispute, of whatever sort, are to be referred to arbitrators and to them alone, the condition is illegal. The one imposes a *condition precedent* to a right of action accruing, the other endeavors to *prevent* any right of action accruing at all. As well put by an English judge: 'If a tenant covenant that he will cultivate the demised land in a husband-like manner and also covenants that if any dispute shall arise in respect thereof it shall be referred to arbitration, an action may nevertheless be maintained; but where the covenant is to pay such damages as shall be ascertained by an arbitrator, no action will lie until he has ascertained them.'

"The principle is frequently applied in the United States to contracts for the construction of buildings, railroads, canals and other works involving numeros details. These contracts give rise to many questions which a court of law might reasonably send to a referee, and the parties may agree that such ques-

tions shall be determined by an architect or engineer or by arbitrators, and that such determination, or a *bona fide* effort to obtain it, shall be a *condition precedent* to the right to bring an action on the contract. Contracts of insurance usually contain similar clauses. Thus an insurance policy provided that, in case of differences arising touching any loss or damage, the matter might at the request of either party be submitted to impartial arbitrators whose award in writing should be binding on the parties to the amount of such loss or damage, 'but shall not decide the liability of the company under this policy;' also, 'it is furthermore mutually agreed that no suit or action against this company for the recovery of any claim by virtue of this policy shall be sustainable in any court of law or chancery until an award shall have been obtained fixing the amount of such claim in the manner hereinabove provided.' It was held that no suit could be sustained against the objection of the company until an award had been made, although neither party previous to the suit had requested arbitration.

"But it must be expressly stipulated in all cases that the award or determination is a *condition precedent* to the right of action on the contract, or the agreement to arbitrate will be of no effect.

"Agreements of a similar nature have been held illegal, as aiming to oust the jurisdiction of the courts; as, for example, a provision in the by-laws of a benefit association that the decision of the officers on the claim of a member shall be final and conclusive. And parties are not allowed by contract to vary the procedure in the courts prescribed by statute. In Illinois a lease contained a provision that the landlord should have the right to take immediate judgment against the tenant in case of a default on his part without giving the notice and demand for possession and filing the complaint required by the statute. It was held that such a provision was illegal."

13. **The Engineer as Arbitrator.** In the carrying out of engineering and building contracts, the specifications are usually so written as to make the engineer or architect an arbitrator on almost all questions which can possibly arise under the contract, and it is usual to specify that his decisions thereon shall be final and conclusive. In view of what is given in the previous article it is evident that such a clause can not operate to prevent a case being brought before the courts under such a contract, but when it has been so brought it evidently will operate to sustain the decisions of the engineer on all points which

may be construed by the court as *"conditions precedent"* to final settlement. On all questions of fact, however, which the court can pass upon as well as the engineer, and on all questions of law the court would retain its jurisdiction notwithstanding the agreement of both parties to submit *all* questions to the arbitration of the engineer, whose decisions were to be "final and conclusive." On all questions which the engineer is, from the circumstances of the case, especially competent to determine, as to quantities and classification, as well as all questions which are more or less matters of opinion as classification of materials and perfection of work done, the decision of the engineer will be sustained under such a clause, provided it be not shown that he has acted fraudulently in the matter. See Articles 85 and 108.

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## AGREEMENT.

14. **Mutual Assent.** In order that a contract shall be binding on both parties to an agreement it must have been understood and assented to by both in the very same sense. However clear the agreement would appear to be on its face, if it can be shown that the proposition was not mutually understood in the same sense it can not, in general, be enforced. It must not be understood, however, that all pleas of having misunderstood the plain and express provisions of a *written* contract will relieve the party making such claim from liability under it. In other words the mental agreement is evidenced by the language used in expressing such agreement, and the law will presume that such words were understood, provided their meaning is plain and evident. Furthermore whatever a man's real intention may be, if he so acts as to lead another person to reasonably suppose that he was assenting to a given proposition, and this person proceeds on this assumption, the other party so acting becomes bound by the proposition.

The agreement is not consummated until each party has communicated to the other, either orally, by letter, or by overt acts, his intention in the matter. The secret or mental acceptance of a proposition by one or both of the parties to it does not complete a legal agreement, until this mental act has been communicated to the other party.

A person making an offer, whether orally, by messenger, by mail, or by telegraph, or by public advertisement, must allow a reasonable time for its acceptance, provided no time limit is stated in the proposition.[1] If the acceptance is returned by the same agency used in sending the offer, the contract is completed at the time such acceptance is delivered to such agency, whether the party sending the offer ever receives such acceptance or not. A person is bound by the acts of the agent of his own selection, and the failure of this agent to deliver to him the acceptance does not operate to prevent the completion of the contract. For instance, a proposition sent by mail is accepted at the time the letter of acceptance is deposited in the postoffice or letter box, and a proposition sent by telegraph is accepted and the contract completed at the time of the delivery of a telegraphic reply at the telegraph office or to a telegraphic messenger.

If the person receiving the offer wishes it to remain open for a definite length of time, longer than might be construed as reasonable, if no time is specified, he must pay to the other party something which may be construed as a consideration for the privilege of acceptance for such specified time. On the other hand, the party accepting can withdraw his acceptance if he can succeed in having his withdrawal presented to the first party before his acceptance has been received. Thus an acceptance by mail may be withdrawn by telegraph, provided the telegram is received before the letter.

A mere offer may be withdrawn at any time before it is accepted, unless a consideration has been paid for the privilege

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[1] This means only that *if not withdrawn* the offer will stand and may be accepted at any time within a "reasonable time."

of acceptance for a definite time as above described. A formal notice of withdrawal is not always necessary, as when the party receiving the offer becomes aware of the sale of the property in the mean time to another.

When an offer is made by mail or telegraph the means used for communicating the offer become the recognized agent of the party making such offer, and the party receiving it is at liberty to accept it as received, even though a mistake may have been made in the transmission of the same. Thus if an offer is made by telegraph, and an error has been made in transmitting the same, the erroneous proposition may be accepted either by mail or telegraph, and the party making such offer is bound. His only remedy is to sue the telegraph company for damages. This is because the party making the proposition assumed all responsibility for the correctness of the transmission by the agency selected by him.

When an offer has been made and no consideration paid to keep it open for a given time, it is supposed to stand for what the law will consider a reasonable time, the actual length of time depending altogether on the nature of the transaction.

**15. Qualified Assent.** Whenever a proposition made by one party is accepted by another with any kind of qualification or change of the conditions or wording of the original proposition, such an acceptance is simply the making of a counter proposition to the first party, and does not constitute an agreement until such party has in turn assented fully to the entire proposition as last stated, and if he again assents to the proposition with further changes or amendments, it becomes again a new proposition, which must be agreed to by the second party, before it becomes binding on the party to whom it is sent. The assent which finally makes of the offer or proposition a binding contract, is the full, absolute, and unconditional acceptance of its terms.

**16. Qualified Offers.** The party making the offer has the right to prescribe in it the time, place, form, or other condition of acceptance, in which case such offer can be accepted only in

the manner prescribed. This privilege on the part of the proposer does not enable him to impose the condition, however, that a failure to receive an acceptance by a certain time will be construed as an acceptance. In other words, he may not impose the conditions of refusal.

17. **Implied Acceptance.** An offer may be accepted by merely acting upon it, the act becoming an acceptance from the time it was performed. Thus an offer to purchase goods may be accepted by simply shipping the goods, or in the case of a published offer of a reward for the apprehension of a criminal, the act of apprehending is construed as both an acceptance and fulfillment of the contract.

18. **Failure of Agreement by Mistake.** The parties to an agreement are bound to the fulfillment of the same in accordance with the plain intent and meaning of the language used, whether oral or written, provided the meaning of this language be clear, and neither party is allowed to plead either carelessness in the reading of the terms thereof or ignorance of the meaning of the language used. It goes almost without saying, however, that apparent or evident mistakes in the use of language will be corrected by the court. However, the following kinds of mistakes will lead to a decision that no contract was really entered into because of utter failure of the parties to agree to the same thing.

(a) **Mistake concerning nature of transaction,** as where a person, by mistake, signs a document of an entirely different character from that which he intended to sign, as where he signs a bond instead of a petition, or a deed instead of a lease, the two documents being similar in form and appearance. In such cases it is held that the "mind of the signer did not accompany the signature" and therefore he never agreed to such a proposition. If it can be shown, however, that the mistake resulted from negligence to read the terms of the proposition, and that while the signer understood in a general way the character of the document, but did not read it over carefully, or perhaps did not read it at all, he will be held to the contract

because of his culpable negligence. This only holds where the plea of fraud on the part of the other party to the contract is not maintained.

(b) **Mistake concerning person with whom contract is made,** as "where A contracts with B, thinking that he is contracting with C, there can obviously be no contract, for B not being present to A's mind, A can not be a consenting party to a contract with B." This, of course, does not affect contracts made through agents, when the agency is declared.

(c) **Mistake concerning Subject-matter of Contract.** If the parties contracting engage themselves concerning a thing which does not exist, such a mistake avoids the contract, because of the nonexistence of the subject-matter. This applies to property which may have ceased to exist before the contract is signed, although both of the parties were ignorant of the fact. In all cases, however, where the existence of the subject-matter is in the mind of the proposer more or less doubtful and yet the offer which he makes is unconditional, he can be held for damages resulting from failure, even though the subject-matter be nonexistent.

A mistake prevents the consummation of a contract also, where each of the parties has in mind a different subject-matter from the other. This applies to mistakes which may be considered legitimate, as where the same words apply with equal force to different things, or in the case of an oral contract where the language was clearly misunderstood, from a failure to hear the words which were really spoken.

The remedy for a contract entered into under a mistake is the privilege of repudiating it on the part of the person who made the mistake, or the privilege of recovering, by a suit at law, part payment which may have been made, it being understood that the contract has not been fully executed by a complete payment. Or the case may be brought into a court of equity, and justice obtained by having the court correct the terms of the agreement, it being assumed in all these cases that no fraud has been committed.

**19. Misrepresentation in the Contract.** In order that a misrepresentation of facts may make a contract invalid, it must have been made with a fraudulent intent. The mere falsity of a statement of a material fact in the contract, however much it may have misled the other party, will not invalidate the document, unless a fraudulent motive accompanied the misrepresentation. It is necessary, therefore, to prove the motive of the misrepresentation before the validity of the contract can be passed upon.

If, however, a particular term in the contract or some integral part of it is based upon a misstatement of fact, which term or integral part can be passed upon separately from the body of the contract, such a misrepresentation is equivalent to a promise by the party making it, and if not fulfilled the other party can recover damages. This, however, does not invalidate the contract as a whole.

A nondisclosure of fact is equivalent to a misrepresentation of fact, provided the disclosure properly accompanied the transaction.

Fraudulent misrepresentation will be treated in the following article.

Contracts for insurance, whether marine, fire, or life, and contracts for the purchase of stock in corporations, also contracts between parties occupying intimate and confidential relations with each other may be invalidated by misrepresentation of fact, which would not invalidate ordinary business or engineering contracts. (See a general treatise on the Law of Contracts for these cases.)

**20. Invalidity of Contract through Fraud.** As a general rule fraud vitiates all contracts. That is to say, fraudulent misrepresentation by one party enables the other or injured party to declare the contract void from fraud, or he may enforce the contract against the defrauding party, at his own option. The defrauding party, however, has no option or privilege in the way of declaring the contract void. In other words,

should he find that the contract was adverse to his interests, he could not plead his own fraudulent act to his own benefit.

Fraud in the sense here used consists in a "false representation of fact made by the party who is charged with it, with a knowledge of its falsity, or in reckless disregard whether it be true or false, with the intention that it shall be acted upon by the complaining party, and actually inducing him to act upon it to his damage."

"From the above definition the following essential elements of fraud may with profit be stated separately: (*a*) A false *representation.* (*b*) A misrepresentation of *fact.* (*c*) A representation made by the *party charged.* (*d*) *Knowledge* of its falsity or a *reckless indifference* in the matter. (*e*) An intention that it *shall be acted upon* by the other party. (*f*) A *reliance* upon it by the other party. (*g*) *Damage* to the party deceived." Unless each and every one of the above essential elements of fraudulent misrepresentation be proved, the contract can not be avoided on the score of fraud.

The false representation also must refer to some material fact. Furthermore the concealment or nondisclosure of a material fact in an active manner, that is to say, an active prevention of the disclosure of material facts, may constitute fraudulent misrepresentation.

Where the one party knows that he is being trusted by the other party and relied upon for the disclosure of material facts, as is the case when a contractor relies upon the engineer or architect to disclose to him the material facts pertaining to the work to be done, this rule will be more rigidly applied than when no such confidence is imposed.

A concealment of the real value of goods shipped by express or freight, or by other agency, in order to obtain such shipment at a lower rate, is a fraudulent misrepresentation.

While the vendor or seller of an article is not obliged to make known to the purchaser the defects of the article, when such defects can be discovered by the buyer, yet a deliberate hiding

of such defects on his part will be considered a fraudulent misrepresentation. As to defects which can not be discovered by the buyer, the vendor is bound to make known to him such defects as he himself may be aware of.

While known false representation of the quality or defects of an article made by either seller or buyer, for the purpose of gaining the advantage in a transaction is fraudulent, the purchaser, however, is not obliged to disclose his knowledge of the real value of an article, which is offered to him below its actual value.

On questions which may be considered matters of opinion rather than questions of fact, misrepresentations do not constitute fraud; only misrepresentations of known facts fall in this category. What is not really known may be misrepresented without invalidating the contract. Neither do false representations of future intention, or of questions of law, constitute fraud.

The fraudulent misrepresentation must have been made by the party charged or by his agent, or with his connivance and knowledge. The fraud of a third person does not invalidate the contract between two others.

The misrepresentation must be known to be false. Sometimes a contract may be set aside because of violent injustice resulting from a false representation, which was, however, believed to be true. Frequently, however, a party may make extravagant statements in a reckless manner for the purpose of influencing the other party to a transaction, not knowing whether his statements be true or not. In such a case the willful negligence or recklessness as to the truth of his positive statements will act to invalidate the contract, provided such statements prove to be false, the same as though he had known them to be false.

The false statements must also be made with the expectation that they are to be believed and acted upon. Extravagent affirmations made in a jocular manner, and not expected to be believed, would not constitute fraud.

The misrepresentation must be accepted as true, and be acted upon before the fraud is perfected. The burden of proof here lies upon the party charging fraud, to show that he did really act upon the statements made. It is not necessary that he shall show that the fraudulent statements formed the sole basis of his action. He need only show that they contributed materially to that end, and that the action would not have been consummated without them.

A false representation as to one of several material matters in a contract operates to vitiate the entire agreement.

The party claiming fraud must also show that some actual damage has been suffered. It would not be sufficient cause for the annulling of a contract to show that one was fraudulently led to the payment of a just debt, since no damage has in this case been sustained.

21. **Remedy of Party Defrauded.** Immediately on discovering the fraud the party defrauded should take action, and he has his option of the following courses, the last two being remedies.

(*a*) He may enforce the contract against the defrauding party, or take no action whatever, and allow the contract to be enforced against himself. If he does not take action on discovery of the fraud, he will be supposed to have consented to the enforcement of the contract, notwithstanding such fraud, and he will lose his option of resisting such enforcement.

(*b*) He may at once give notice of the rescission or rescinding of the contract on his part, because of fraud claimed to have been perpetrated by the other party, and he may bring suit to recover damages, or he may either by word or act give evidence to the other party of his intention to treat the contract as null and void.

(*c*) If it be practicable to reinstate the parties in their original relative relations, he may sue for such restoration. That is to say, if goods have been delivered, they may be recovered if practicable.

Any action under the contract in the way of acknowledging

its force by the party defrauded, after he has discovered the fraud, will operate to make the contract binding upon him, as he will be assumed to have deliberately forfeited his right of rescission. It must be understood, also, that he can not consent to the operation of a portion of the contract with the privilege of rejecting another portion of it to which the fraud may more directly relate. Since fraud vitiates the entire contract, the defrauded party must forfeit his privilege of rejection entirely by agreeing to its terms notwithstanding the fraud, or he must reject it entirely and in all its parts. He can not obtain the benefit of a part and reject another part.

Outside of the rights described above, arising under the contract itself, the defrauded party has the privilege at common law of bringing action for deceit to cover such damage as he may have sustained as a result of such fraudulent misrepresentation. This action is in addition to his privilege of avoiding or rescinding the contract itself.

Furthermore a party defrauded of his property may recapture it, if he is able to do so without unnecessary violence and without a breach of the peace, without recourse to the law and its agencies.

**22. Invalidity of Contract through Duress.** "A person is said to have acted under duress when he does or promises to do any act not of his own free will, but in consequence of unlawful physical restraint imposed by another, or in consequence of threats made by another, either to do him some great bodily harm, or to unlawfully destroy his property, or deprive him of the same. Promises made under duress will not be enforced, and money paid, or property transferred under duress may be recovered."

Contracts entered into under duress as above defined are voidable at the option of the constrained party, the same as though fraud had been perpetrated upon him. The contract is not voidable, however, at the option of the other party.

**23. Invalility of Contract through Undue Influence.** Where the parties occupy a confidential relation to each other,

or from long association and other peculiar circumstances affording the proper and sufficient opportunities, courts of equity take cognizance of what may be called undue influence, which may act the same as fraud in persuading the person to enter into an unfair and unreasonable contract. Such are the relations of the members of one family, or those of guardian and ward, attorney and client, priest and parishioner, physician and patient, as well as those where mental weakness from old age or sickness and the like, furnish suitable opportunities.

The remedies in the case of undue influence are the same as those in the case of fraud, except that the influenced party does not lose his rights of choice of remedies by delay in action, since it is unfair to assume that such a party can suddenly recover his normal independence.

## CONSIDERATION.

24. **Consideration Defined.** All business contracts such as an engineer will be called upon to enforce must always be supported by a *valuable consideration;* otherwise they are not enforceable. As such a consideration is always named and specifically determined in all engineering contracts, it is not necessary to go into that subject here very fully.

A "valuable consideration" in the eyes of the law is *"some right, interest, profit, or benefit, accruing to one party, or some forbearance, detriment, loss, or responsibility given, suffered, or undertaken by the other."*

Such a consideration is necessary to enforce a written agreement the same as would be necessary with an oral agreement.

A contract under seal, however, does not require a consideration to enforce it. This is the principal and characteristic difference between contracts under seal, and ordinary written or oral contracts, both of which latter class constitute what is known as simple or parol agreements.

It is not necessary that the consideration be named in the agreement, or that the fact of consideration should appear in the agreement; it is only necessary that there shall be a consideration in fact.

In cases of promissory notes and other negotiable paper, the presumption is that there was in fact a consideration, whether named in the document or not, and the burden of proof rests upon the maker of the note to show that there was in fact no consideration.

In the states of California, Iowa, Indiana, Kansas, Kentucky and Missouri, an agreement made in writing is presumed by statute law to be founded on a consideration, and is therefore placed on the same basis as holds generally for negotiable paper. Here again the burden of proof rests upon the defendant to show that there was in fact no consideration. In both the above cases if it can be shown that the promise was not supported by what the law will construe as a valuable consideration, the agreement or contract fails. But mutual promises are each a consideration to support the other.[1]

A promise made without a valuable consideration is construed by the law to be gratuitous, and not enforceable, even though the party to whom it was made has acted upon it, and has sustained serious loss or damage thereby.

**25. Adequacy of Consideration.** It is not necessary that the consideration named, or implied, or shown to exist by anv acceptable evidence shall be adequate to support the promise. So long as it is valuable at all, in the sense defined in the previous article it will support the full promise. The question of adequacy of consideration will not be allowed to be put in evidence except for some ulterior purpose, as when it is attempted to prove fraud.

Here the law seems to conflict with the principles of right and justice; but for the court to inquire into the adequacy of a consideration would make nearly all contracts subject to litigation and the freedom and rights of the individual would be

[1] This is termed a *bilateral* contract.

greatly curtailed. This rule as to adequacy, however, does not apply to the exchange of sums of money, for instance, whose absolute values are fixed and known. In this case the consideration must be adequate and equal.

When the consideration is grossly inadequate, suit may be brought in equity and the courts will in that case sometimes vary the terms of the agreement in the interest of justice.

Neither is it necessary that the consideration should have any assignable money value, as is plainly implied in the definition of a consideration given in the previous article. Thus mutual promises are each a consideration for the enforcement of the other, but when the promise of one of the parties includes no more than it was already his legal duty to perform, such a promise will not support a promise made by the opposite party. For example, if A owes B a sum of money, and interest thereon which *is due,* and A promises to pay B the interest if he will extend the loan, which B promises to do, here B's promise to extend the loan is not supported by a valuable consideration and is therefore not enforceable. Again, a promise to pay to a public officer more than his lawful fee for the performance of a public duty, is not enforceable.

**26. Agreement to Take Less than is Due.** A very common case in the execution of contracts is that of an agreement by one of the parties to receive or accept less than the contract calls for. It is important here to distinguish between sums of money or matters which are in dispute, and sums of money or matters which are not in dispute.

If one of the parties agrees to accept a sum of money less than that which is avowedly due him, such an agreement is not enforceable, because of failure of consideration, unless some condition of performance accompanied the offer which may be construed as a consideration. If, however, the sum of money claimed by A is disputed by the other party B, and never has been acknowledged by B as being the amount owed, then and in that case an agreement on the part of A to accept less than his claim, when accepted by B, is enforceable. This is because

no agreement had been made previous to this compromise arrangement.

Similarly an agreement on the part of the owner to accept a less amount of work or a cheaper construction on the part of the contractor than that contained in the written specifications is not enforceable, unless it is supported by some further act on the part of the contractor, or by a corresponding change in the price of the work, which may be construed as a consideration. If, however, the original contract provided for such changes as these by agreement without further consideration, such further agreements simply modify the terms of the original contract and become a part thereof without a new consideration being required.

Where several creditors enter into a mutual agreement among themselves and with the debtor to take less than is acknowledged to be due them, and to discharge their several debts, such an agreement is held to rest on a sufficient consideration, since these mutual promises are evidently for their mutual benefit, and therefore all do receive a valuable consideration in support of such promises.

If it is desired or intended that an agreement shall hold without a corresponding consideration, such as have been referred to above, it is only necessary to execute the new agreement under seal, in which case a consideration is not required.

When a person brings suit against another or threatens to do so, for a sum of money claimed in good faith to be due, not evidenced by a note or promise to pay, the dismissal of such suit, or a promise not to bring it, is a sufficient consideration for a promise by the party sued, or threatened to be sued, to pay to the claimant a sum of money, or for a promise to do any other lawful act.

In the case of an engineering contract, an agreement by the parties to vary the terms of the original contract, which variation may not have been provided for in such contract, an agreement to vary the conditions in one particular must be supported by a consideration in the way of an agreement to vary the terms

of the original contract in some other particular which may be accepted as a consideration, or some other and new consideration must be provided for in order to support such agreement. Thus, if A has agreed to build a house for B in accordance with certain plans and specifications with no provision for changes of plan, if B consents to a change in the plans by which the cost is reduced, without any consideration being agreed upon or mentioned for such change of plans, B has the privilege of changing his mind, and of enforcing the original agreement, since the second agreement was not supported by a consideration. In like manner, should A consent to a change of plans without naming a consideration he can not be held to such an agreement even though it be made in writing, but may continue to carry out the original agreement, which alone is binding. In other words, all subsequent or auxiliary agreements or changes in the original contract not provided for in the original document are in fact new contracts and must each and all be supported by a consideration.

Promises or contracts which have been fully executed can not be inquired into by law, as to whether there may have been no consideration. Thus money which has been paid without consideration can not be recovered, and for work executed before a promise to pay has been given or implied, no recovery or compensation can be obtained.

Of this general character are gifts which have been made, the article having been delivered to the donee. They can not be recovered, neither can payment for them be enforced. An exception to this is where property has been given away to defraud creditors. In this case the person receiving the gift may be compelled to restore it to the creditor, or so much thereof as will discharge the creditor's claim against the donor.

**27. As to Waiver of Legal Rights.** An apparent exception to the general rule that a promise must be supported by a consideration is an agreement to waive a statutory right of defense. Thus "a promise to pay a debt barred by the statute of limitations, or by a discharge in bankruptcy, though made

without consideration is enforceable, and a promise by an endorser of a bill or note to pay it, although the endorser knows that he has been released from all liability, from the note not having been protested when due, is likewise binding." In these cases the new promise is equivalent simply to waiving the legal rights of the party, after which the old promise is again restored to its legal status, which former promise was supported by a consideration.

"But when a debt has been canceled by the act of the parties, as by a release under seal, which would require no consideration, a subsequent promise to pay the debt, notwithstanding the release, is not valid unless supported by a consideration." In this case the former promise or agreement had been obliterated by a subsequent release under seal, and hence a new contract would have to be made.

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## CONTRACTS UNDER SEAL.

**28. Classes of Sealed Contracts.** While any contract may be executed under seal, and so become a sealed contract, *under the common law,* the following must be executed under seal to become binding, namely: (*a*) Gratuitous promises. (*b*) Contracts with corporations. (*c*) Conveyances of real estate. (*d*) Bonds.

(*a*) If it is the purpose to make a gratuitous promise legally binding on the parties, it must be executed under seal, and when so executed the absence of a consideration will not invalidate it.

(*b*) The common law rule that contracts with corporations must be executed under seal no longer obtains in the United States. Here a contract entered into with the proper officers of a corporation is valid without being sealed, the same as though made with an individual, unless the charter of the corporation specifically requires all contracts to be made under seal.

(*c*) Deeds and mortgages do still in this country require the presence of a seal, except where a special statute provides otherwise.[1]

(*d*) A bond is an instrument under seal whereby one acknowledges himself indebted to another in a specified sum, generally but not necessarily conditioned on the performance of some act. Thus bondsmen or sureties in the case of an engineering contract are those who sign an obligation or acknowledgment of indebtedness in favor of the party letting the work, in a specified sum, conditioned on the faithful execution of the work which the contractor has undertaken to perform. Such an instrument, called a bond, should be executed under seal.

The significance of a seal is losing its force in America. In some states a seal no longer has any significance whatever, so that even when present in due form, it does not import a consideration, but such consideration must be proved the same as for a simple or parol contract. The plain intent of the parties is the controlling factor. The rules given above are the common law rules and still have more or less force in some states.

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## PAROL CONTRACTS.

**29. Oral and Written Contracts.** All contracts, either oral or written, not executed under seal, are called simple or parol contracts.

An oral contract has all the force of a simple written contract, but it is subject to difficulties in the way of establishing or proving its terms, which a written contract is comparatively free from. A large proportion of the litigation arising from the nonfulfillment of contracts is caused by a failure to reduce the terms of the contract to writing.

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[1] This is true in Ohio, Indiana, Iowa, Kansas, Nebraska, Tennessee, Texas, Kentucky, and Mississippi.

An oral or written contract can be modified by subsequent agreements, and such subsequent agreements become a part of the original contract. A written contract, however, has this advantage over an oral contract: It is presumed in law to embody all understandings and agreements made at the time of, or previous to, the signing of the contract. No oral evidence can be admitted therefore as to agreements or understandings made at the time of the written agreement or antecedent thereto which would modify its terms. Evidence will be received, however, as to oral or written agreements made subsequent to the signing of the written contract which may modify its terms.

It is allowable, however, to admit testimony as to oral agreements or understandings made prior to, or contemporaneous with, the signing of the contract, for the purpose of proving fraud and deception.

Such evidence may also be introduced for the purpose of proving duress or mistake in the drafting of the contract. It can not be introduced for the purpose of modifying its terms, since it must be assumed that all the essential or material matters in the agreement were embodied in the written contract.

Subsequent oral or written agreement modifying the terms of the original contract requires a separate and distinct consideration to support it, unless the original contract contained special provision for such changes, in which case they must be made in accordance therewith, and may or may not require a new consideration.

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## ASSIGNMENTS OF CONTRACTS.

**30. When Assignments Can Be Made.** All contracts and agreements can in general be assigned by either party, and the contract enforced by the assignee, except such contracts or agreements as involve a personal trust or confidence in one or both of the parties. Evidently trust and confidence in the skill

or professional ability of another can not be assigned, and when such trust is a material element in the contract there can be no assignment. Of such character are nearly all kinds of personal services, except, perhaps, the most common labor.

All building and engineering contracts are assignable, unless the writings themselves contain conditions denying such privilege. It is, however, common to insert such a clause in all engineering contracts by which they then become nonassignable.

31. **Notice of Assignment Necessary.** While an assignment is effectual as between the assignor and assignee, from the moment it is made, it does not bind the other party to the original contract until he has received notice of the assignment. Without such notice any performance on his part in favor of the original party or assignor releases him to that extent with the assignee. It is necessary, therefore, to give prompt notice of all assignments to all the parties concerned. After such notice has been given, all parties become bound to the assignee, the same as they had formerly been to the assignor.

An exception to the rule of the necessity of giving notice obtains in the case of what is called negotiable paper. The transfer of such contracts is not called assignment, the document itself carrying with it its own evidence of ownership. Such documents are bills of exchange, bank checks, promissory notes, bills of lading, certificates of deposit, certain kinds of bonds and coupons, warehouse receipts, and bank bills.

## CONSTRUCTION OF THE CONTRACT.

32. **The Original Contract.** An original written contract is presumed to embody all the agreements made at, or previous to, the time of its signing. No oral evidence will be admitted to explain or supplement the terms expressed in the written contract, provided these are clear and plain. It is permissible,

however, to modify the terms of any written contract by subsequent oral or written agreements. It is also permissible to submit evidence as to contemporaneous oral agreements which supplement or explain the terms imposed in the contract, provided these be not inconsistent with the terms of the written document.

Oral evidence is also admissible to explain the identity of the parties, or the existence of an agency, the identity of the subject-matter, and the sense in which certain unusual or technical words have been used.

Oral evidence is also admissible to explain any latent ambiguity in the instrument, as where more than one meaning may be given to a word or phrase; but in the case of a *patent* ambiguity, that is to say, an ambiguity apparent on the face of the instrument itself, and which is meaningless without oral explanation, such an ambiguity will make the contract void.

33. **The Explanation of Technical Terms in Contracts.** In all cases where either common or uncommon words are used in a technical sense, or in a sense peculiar to a given trade or business, in which custom has given to such expressions particular and definite meanings, oral testimony can be received for the purpose of explaining the real meaning of such terms. Furthermore, the meaning which the law will enforce is that which such a term has in that neighborhood, or with the parties to the contract. In such cases the common usage or custom will fix the meaning of the technical words used.

In other cases oral evidence may be introduced to explain the real meaning of a contract, where custom or usage caused the meaning to be clear to the parties themselves when the contract was signed, but which would not be understood by strangers to such usages.

In order that a contract may be interpreted in the light of custom or usage, such custom or usage must be certain, definite, and uniform in that district, or between the parties to the contract. Unless it is a universal custom or usage as between the parties, it can not be received as positive evidence of meaning.

Furthermore such custom and usage must have been continuous and uninterrupted up to and including the time of the transaction in question. Thus one or more acts do not establish a custom as between the parties, and a few illustrative examples will not serve to establish a usage.

When the explanation rests upon usage in the neighborhood, such usage must be general and a knowledge of it must be common, so that it may have been presumed to have been known to the parties to the contract.

Such custom or usage must be reasonable, and must have been generally assented to, and complied with without protest, in order to become binding in explaining the terms of a contract.

Such custom or usage, also, must not be repugnant to any of the express terms of the contract itself, neither must it contravene a state statute, city ordinance, or conflict with the law of public policy.

34. **Rules of Construction.**

*1.* The first and principal rule to be followed in the construction of contracts is to ascertain the real intention of the parties at the time the contract was signed. In fact all rules are merged in this one, and have for their object the determination of the original real meaning of the document.

*2.* In arriving at this real meaning, the words used must be understood in their ordinary and popular meaning, when these do not have a technical significance, as indicated in the previous article. In all other cases, the language is supposed to mean what it would ordinarily be understood to mean under the given circumstances of time and place, and as between the given parties.

*3.* Furthermore the whole instrument must be looked to, and all the terms thereof made effective if possible. The whole instrument will be construed, also, in construing any latent ambiguity which may pertain to any given part. Where more than one document enteres into a general agreement they shall all be taken into account in the construction of the entire contract.

Words may be wholly rejected which are inconsistent with the manifest intention of the parties.

If a portion of the contract is printed and other portions written, the latter will take precedence over the former, when they are found to conflict.

Where both general and specific terms have been used in describing the same thing, the agreement will be limited to the scope of the more specific terms, and may not be applied to the more general.

Doubtful words will be construed more strongly against the party who used them. This is based on the principle that a man is responsible for ambiguities in his own expressions. Thus a deed is construed most strongly against the grantor, and a clause in a promissory note will be construed most strongly against the maker. Such a prejudice, however, is never exercised against either party, if possible to avoid it.

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## CONTRACTS REQUIRED TO BE IN WRITING.

35. **The Statute of Frauds.** In the year 1676 the English Parliament passed "An act for the prevention of frauds and perjuries" which has become common law for this country where it is not replaced by statutes in the various states covering the same ground. In either case where reference is had to the original English enactment or to the corresponding statutes in the various states, this law is commonly referred to as the "Statute of Frauds." The object of such a law is to prevent litigation and fraud by requiring certain kinds of contracts to be in writing. These in general relate to the official acts of executors or administrators, marriage contracts, to the sale and transfer of real estate, to agreements which can not be performed inside of one year, and other contracts for the sale of goods, wares, and merchandise of a value greater than $50. As only the last two of these pertain to the character of the present work they alone will be discussed here.

**36. Agreements Which Can Not Be Performed within One Year.** The English statute provides that "no action shall be brought whereby to charge any person upon any agreement that is not to be performed within the space of one year from the making thereof, *unless* the agreement upon which such action shall be brought, or some memorandum or note thereof, shall be in writing and signed by the party to be charged therewith, or some other person thereunto by him lawfully authorized." That is to say, contracts which can not be performed within one year from the date thereof must be in writing. This is construed as meaning that the necessity for a written contract only holds when the performance within one year is demonstrably impossible. If by any possibility it may be fully performed within one year, an oral contract is valid.

Thus a contract for a year's service, to be entered upon at a future time, can not be performed within one year, and hence must be in writing. Or in the absence of a written contract to this effect an oral agreement can not be enforced, and either party is at liberty to annul the contract at pleasure. Where services have been rendered, however, under an oral contract which by this clause ought to have been in writing, the party benefited must pay for them.

Thus, also, a contract for the carrying out of any engineering construction, if it plainly can not be completed within one year, is not binding, unless it be in writing.

**37. Contracts of Sale Where the Value Is More than $50.** Another clause in the same original English statute reads as follows: "No contract for the sale of any goods, wares or merchandise, for the price of ten pounds sterling or upwards, shall be allowed to be good except the buyer shall accept part of the goods so sold, and actually receive the same, or give something in earnest to bind the bargain, or in part of payment, or that some note or memorandum in writing of said bargain be made, and signed by the parties to be charged by such contract or their agents thereunto lawfully authorized."

Similar statutes have been enacted in this country in which

the limit of the value of the goods sold is usually placed at $50, while in Maine and in New Jersey it is placed at $30. For all values over these amounts the contracts must be in writing or, as stated in the statutes, the buyer must give proof of his agreement by accepting and receiving a portion of the same or by part payment for the same.

It must be noted, however, that a contract for labor is not included in the statute. The limit of value here used applies not to individual articles but to the sum total of the articles named in the transaction.

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## SUBSEQUENT CHANGES AND AGREEMENTS.

**38. The General Rule.** In general any oral or written agreement may be altered at pleasure after it has been signed, when this is done by mutual consent. Alterations made at the time of, or previous to, the signing of the instrument become elements in the original contract.

Any change by mutual consent in the terms of an agreement after it has been signed makes a new contract out of the original agreement, and because of this a surety or a third party to the agreement not consenting to the change is released from all obligation. The new contract remains good as to those who consent to the change. In the case of engineering contracts where it is common to have sureties or bondsmen who guarantee faithful performance, such sureties must always be consulted and their consent obtained to any material change in the original contract which may be mutually agreed on by the principals. In default of such reference and consent on the part of the sureties, they become discharged from all liability.[1]

Even though the written contract has a clause forbidding any oral alteration in it, and declaring that no change shall be made in it except in writing, such a provision is void, and the

[1] See special clause, to be inserted in the bond itself to provide for such changes, p. 508.

contract may be altered by oral agreement notwithstanding. This is because in law oral and written agreements are of the same class, both being simple or parol contracts, and hence are of equal force and effect. An agreement in writing, therefore, by the parties, to forfeit their legal rights, does not operate to change the law in this respect, and their rights can not be forfeited by such an agreement. One of these rights is the privilege of modifying the contract by oral agreement.

Where contracts are illegal except when they are in writing, as under the Statute of Frauds, it follows that such a written contract can not be modified by oral agreement, since this would circumvent the law as applied to such cases. This also applies to promissory notes and other commercial paper. Oral agreements in regard to them are invalid, as they would work injustice to innocent parties.

Written contracts executed under seal, not required by law to be so, may be modified or altered by either written or oral agreements, but when this is done the whole contract is reduced to the force and significance of a simple or parol agreement, and no longer remains a specialty.

Furthermore this can only be done in the case of a sealed contract, when the new agreement or alteration rests upon a new and separate consideration. Where the seal is required by law, alterations must also be made under seal. If, however, all the parties to the original agreement are together, and the instrument is changed by the principals who signed and sealed it, in the presence of all, and with the consent of all, the alterations are valid.

39. **Results of Alterations of the Contract.** This is one of the most important subjects connected with the execution of engineering work. Very seldom is an engineering or architectural project constructed strictly in accordance with the original plans and specifications. Usually the contract itself provides for changes in plans and specifications, and in general changes must be made in accordance with such provisions.[1]

[1] One exception to this rule is given in the previous article, where the contract provides that changes shall be made only in writing.

While the court decisions are extremely various and frequently directly opposed to each other in their enforcements of contracts which have been changed more or less after they have been signed, it is thought the following is a fair interpretation of the intent of most of the authorities in passing on such cases:

(*a*) Changes in the contract will not operate to annul the original contract unless such was the plain intent of the parties, and so long as any portion of the original contract may fairly be construed as remaining in force.[1]

(*b*) In general, every change made in a contract after it has been signed should be based on some kind of a legal consideration. Thus, if a change is made which involves an addition to the cost of the work, it should be accompanied and sustained by a corresponding increase in the compensation or price, or by a corresponding reduction in some other part of the work, or by a corresponding accommodation of some character in favor of the other party, which may be construed as a consideration for the change made. Otherwise the change agreed upon can not be enforced.

(*c*) Similarly, if the parties agree to a less performance than that required by the contract, unless there be also a corresponding reduction made in the price, or some other accommodation to the other party, which may be construed as a consideration, the agreement can not be enforced against the party making the concession. He is at liberty to change his mind.

(*d*) In such changes as are mentioned in (*b*) and (*c*) the law will not inquire particularly as to the adequacy of the consideration, so long as a legal consideration may be shown to exist.

(*e*) An apparent exception to the above rules of construction is that in which the original contract provides for changes to be made in a specific manner, and without further consideration. Thus it is sometimes specified and agreed upon that the character of the materials or the methods described in the orig-

[1] It is sometimes expressly stipulated in the original specifications that subsequent changes shall not operate to annul those portions of the contract with which these changes are not in conflict.

inal contract may be changed at the pleasure of the engineer or architect, without further consideration. In this case any change made consistent with this provision would not be regarded as a new contract, but simply as a sort of construction of the old agreement. Under such a clause, however, the law would not allow a gross injustice to be worked against the contractor in the way of violent changes which would greatly increase the cost of the work, and which evidently were not anticipated by the parties to the contract at the time it was signed.

(*f*) In all cases where changes have been made in a contract, if such changes involve an increase in the time required for performance, the date of completion of the work fixed by the original contract will be extended by the courts for a period sufficient to cover the additional time required for the changes made. This the courts will do whether such extension of time be provided for, either in the original contract, or in the subsequent agreement.

(*g*) It is customary to include in the original specifications a clause describing the manner in which all changes in plans and specifications may be made, and the compensation for the same determined. In this case changes in the contract must be made in accordance with such provision, and such changes, when so made, are binding upon the contractor, whether he consent or not. They might operate, however, to release the bondsmen.

(*h*) All contracts, except those required by law to be in writing, whether sealed or unsealed, can be modified by oral as well as by written subsequent agreement, regardless of any provision to the contrary in the body of the original contract.

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## DISCHARGE OF CONTRACTS.

**40. Methods of Discharge.** Any contract entered into in any of the methods heretofore indicated may be discharged and the parties thereto freed from all obligations thereunder in

any one of the following ways: 1. By agreement. 2. By performance. 3. By impossibility of performance. 4. By operation of law. 5. By breach.

41. **Discharge by Agreement.** Any contract which has been entered into by mutual agreement may evidently by mutual agreement be dissolved. This may be done, (*a*) by a waiver or cancellation, (*b*) by a substituted agreement between the parties, or of the contract, (*c*) by a condition in the contract itself.

(*a*) An agreement to discharge the contract must be supported by a consideration the same as any other agreement. The usual consideration in this case is the mutual release from liabilities under the original contract.

(*b*) A contract may be discharged by the substitution therefor of a new agreement, the consideration in this case being as before the mutual discharge of obligation under the previous agreement. This new agreement may be either oral or written, and it will serve to replace or rescind the previous agreement if such were the intention of the parties. This is true whether the original agreement was a sealed contract or simply a parol agreement. If, however, the original contract was required by law to be in writing so must also the new contract which replaces it.

The rescission of the former contract may be implied, as where the terms of the latter agreement conflict with those of the old, the later agreement taking precedence and discharging the former. The intention to discharge the former, however, must be clearly implied from its being the only rational assumption in the premises.

The contract may be rescinded by the substitution of a new party to it in place of one of the original parties. This may be done only where all parties to the contract are agreed, this agreement being either express or implied by subsequent acts.

(*c*) The contract may contain a provision for its own discharge on the happening of some event or contingency. This contingency may be the nonfulfillment of some specific clause

in the contract itself, or on the occurrence of some particular event, or on the exercise by one of the parties of an option to determine it. When the event transpires which forms the condition of the discharge, the contract is thereupon rescinded.

Engineering contracts sometimes contain a clause to the effect that the work may be stopped at any time with a specified notice at the option of the party paying for the same.

42. **Discharge by Performance.** The usual method of discharging a contract is by each party fully performing the duties prescribed for him in the agreement. In this case the performance by each party must be strictly in accordance with the terms of the contract.

In engineering work it is seldom that the work is done in all details strictly in accordance with the plans and specifications, or with such plans as are authoritatively modified by the engineer. While in law the contract requires a strict and full compliance with all the terms of the agreement, yet in equity a substantial compliance is accepted in place of a full and complete performance. Also in equity an imperfect compliance is often taken as a discharge of the contract subject to such damages as would equitably compensate for the degree of failure to fully and completely satisfy the agreement.

One of the essential requirements of the contract is the time specified for the completion of the work, when this is so named in the agreement. When no time limit is mentioned in the agreement, the element of time is not deemed to be of the essence of the contract, but performance will be required within a reasonable time. When a specific time or date is given for completion, a court of equity will examine as to whether the intent of the parties was to determine in a general way the time when performance was expected or whether such limit was intended to be a specific and essential part of the contract. If the former meaning is imposed no relief can be had in equity for nonperformance within the specified time.

43. **Performance on Conditional Promises.** In engineering contracts performance on the part of the owner is usually

conditioned on a previous performance on the part of the contractor. On the other hand, the owner sometimes agrees to make payments, for instance, at specified stages of the work, in such a way that further performance on the part of the contractor may be conditioned on the making of such payments at the times specified. Performance may also be conditioned in various other ways, as after the lapse of a certain time, or upon the occurrence of a particular event or contingency which may be uncertain, or on the acts of a third party, or even on the will of the promisor. In this last case it is really no contract at all, so far as the promisor is concerned. That is to say, while he can enforce it against the other party, the other party can not enforce it against him. Such a case as this last is where one party agrees to do work to another's satisfaction.[1] Here the party performing the work is wholly at the mercy of the party to be satisfied, and the plea of dissatisfaction relieves him from liability.[1] Evidently no person should place himself thus at the mercy of another, unless he can rely implicitly upon the good faith of the other party.

A common instance of the operation of a "condition precedent" with reference to a third party is where a contractor binds himself to receive payments on a building or engineering work *only* on the certificate of the architect or engineer. Without such certificate which forms a "condition precedent" the owner is not obliged to make payment. Before the contractor can force the owner to pay him for his work, in the absence of such a certificate from the architect or engineer, he must be able to prove that the architect or engineer has acted fraudulently in withholding the certificate, or that he has acted under gross mistake, and in bad faith, or has negligently refused to honestly examine the work. As this is, of course, very difficult to establish, the refusal of the architect or engineer to give such certificate commonly acts as a bar to payment under the terms of the contract.

Also where the quality or quantity of the work to be done

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[1] The courts will construe this as meaning a *reasonable satisfaction.*

is, by the terms of the contract, to be left to the approval of a third person, such as the engineer, his decision in the premises is binding upon both the parties.

The agreement may be conditioned upon a notice being given to the promisor, as where the engineer is required to give notice to the contractor to begin work at a certain time. In this case the proof of having given such notice is necessary to the enforcement of the contract.

44. **Discharge by Payment.** The discharge of a contract by full payment of money due upon it requires no further comment in this connection. This subject is further amplified in the works on the "Law of Contracts," but it is not necessary to elaborate it here.

45. **Discharge by Tender.** When the performance of a contract is frustrated or prevented by the act of the party to whom the performance is due the offering to perform is called a tender. As applied to engineering contracts, if the contractor is prevented from performance by the owner, the latter subjects himself to liability on a suit for damages sustained by the contractor by not being allowed to perform. In other words, the owner breaks the contract by his refusal and subjects himself to a suit for damages, the same as in any other case of breach of contract, while the contractor stands released from all further obligation under the contract, his tender being construed as performance so far as he is concerned.

46. **Kinds of Impossibility Which Will Discharge a Contract.** An agreement between parties to do what both know to be impossible is discharged when their knowledge of such impossibility is shown, but where the impossibility is known only to one of the parties, he is liable for damages to the party to whom it is unknown.

Where the subject-matter is nonexistent, or has ceased to exist, the impossibility of performance results from a mutual mistake of fact, and the contract is discharged.

Where performance is rendered impossible by what is called in law "an act of God or of the public enemy" the party so con-

tracting is excused. By "an act of God" as used in law as discharging a contract is meant a manifestation of the powers of nature over which man has no control, such as fires caused by lightning (but not by accident or other cause), winds, floods, sickness and the like. In the performance of engineering contracts unusual difficulties will not be placed in this category, *so long as they are by any possibility under human control.*

While as stated above an "act of God or of the public enemy" making performance impossible, will discharge a contract, yet it must be clearly shown that such "act of God or of the public enemy" did in fact render the performance quite impossible, and not simply difficult or expensive. Thus if wind, flood, or lightning should destroy a partly completed engineering work, if it were possible to re-erect it within the time specified, the contractor would be held to full performance.

47. **Kinds of So-called Impossibilities Which Will Not Discharge the Contract.** "When a person contracts to do a given act he pledges himself as having the capacity to do it, and assumes the risk of being prevented from performing his contract by obstacles or accidents; against obstacles or accidents that may interfere with performance *he should protect himself by contract.* Having presumed generally to do a thing he can not allege that difficulties and obstacles prevented him from fulfilling his contract, although they did in fact render the doing of the thing *by him* impossible. He is bound to do whatever is within the scope of any human being to accomplish."

From the above which is quoted from Judge Amos Thayer, of the United States Court of Appeals, it is evident that if a contractor wishes to obtain release from full and complete performance for certain contingencies, as, for instance, inability to obtain material, or to place sub-contracts, or to get the subcontractors to comply with their agreement, or to provide against labor strikes, whether in the trades or on the railroads, or against the inclemencies of the weather which might make performance within the time difficult and very expensive, or

against any other of the extraordinary contingencies which may arise to prevent performance except at great loss, he must evidently provide protection for himself in the body of the contract. In the absence of such a protection and under a simple agreement to perform certain work within a certain time, the law will hold him to a strict compliance, *so long as such compliance lies within the realm of human possibility, regardless of expense.*

48. **Discharge of Contract by Operation of Law.** There are various methods by which a contract may be discharged through the operation of the law, as, for instance, by merging one contract into another, by a fraudulent alteration of the written agreement, by the bankruptcy of one of the parties, or by death. In the case of the death of one of the parties, the contract is discharged only when this is made a condition in the contract, or when performance thus becomes impossible. It will become impossible when the performance is required to be of a personal character, as contracts for services, or such as require professional skill, marriage contracts, and the like.

49. **Discharge of Contract by Breach.** While any material breach of the contract on the part of either of the parties furnishes a right of action to the injured party, it is only in exceptional cases that such a breach operates to discharge fully the other party from his obligations. The contract will be discharged as to the injured party by a breach by the other party:

(*a*) When one of the parties announces his positive renunciation of the contract, whether this be previous to a partial performance, or after a partial performance. In this case the injured party is entirely relieved from further obligation, or in other words, the contract is discharged. Suit may at once be entered for damages. When the renunciation is only partial, and does not affect a vital portion of the agreement, the contract remains in force, but a suit for damages will lie. The injured party is, however, not bound to treat a formal renunciation as a breach of contract, but may insist on performance until the specified time has elapsed.

(*b*) By one of the parties making it impossible for him to perform his agreement. When this impossibility of performance comes to the knowledge of the other party, he may at once consider the contract discharged, and may enter suit for damages.

(*c*) By such a failure to perform in case of a "condition precedent" or failure which goes so to the root of the matter that a recovery of damages would not satisfy the agreement. When the performance of one of the parties is clearly made a "condition precedent" to performance on the part of the other, a failure to substantially perform on the part of the one operates to discharge the contract as to the other.

In engineering contracts a "condition precedent" to the final payment on the part of the owner is usually the certificate of performance to be given by the engineer or architect, he being a third party, and not one of the principals to the agreement. In this case a failure to give such certificate does not operate to discharge the contract between the principals, but does excuse the owner from making a final payment unless it can be shown that the engineer or architect has failed to perform his duties in this respect.

In determining whether or not the failure to perform on the part of the contractor, for instance, is so vital as to operate to discharge the contract entirely as to the owner, and release him from all obligation to pay for the work done, we may distinguish between divisible and entire agreements. A contract or agreement may be considered divisible, when a fulfillment in part is valuable to the other party so far as it goes, and when a failure as to a part does not operate to destroy the value of the partial performance. Thus a contract to build two houses is a divisible contract, since the building of one would be a satisfactory performance as far as it goes, and a failure to build the second would not operate to destroy the value of the first; whereas a contract to build a house is an entire contract, since the building would not be serviceable until fully completed.

The degree of failure to perform, as in the case of agree-

ments by contractors and builders, which will operate to discharge a contract on the part of the owner, must be determined by the court or by a jury. In general any substantial failure to perform an indivisible contract will operate to discharge the contract. If, however, the work done or goods delivered are accepted and used, the law will create a new and implied contract on the part of the recipient and beneficiary, by which the party supplying the service or goods can recover a fair price for the same. Such recovery, however, not being under the contract or in accordance with its terms.

A failure in minor details does not, as a rule, discharge the contract, but simply furnishes to the other party the right to obtain damages to the extent of the failure. It is very important to note, however, that such failures which give to the injured party only the right to recover damages must be in their nature insignificant, and of small relative importance, not in any sense going to the root of the matter or affecting the value of the parts which have been satisfactorily performed. The law is very severe in enforcing agreements literally and fully, especially where departures have been made intentionally and perhaps against the protest of the other party. In such cases even small failures to comply may be considered as a discharge of the contract. Where the contractor has evidently acted in good faith, much larger failures to perform may be remedied by a payment of damages instead of operating to discharge the entire contract.

When a failure to perform pertains to work which must either be accepted and used, or removed at great expense, as where a structure is built upon the owner's land, if such structure fails materially to comply with the terms of the contract, such failure to perform will operate to discharge the contract without compensation to the contractor, even though the owner does accept the work and use it. In this case the owner is not at liberty to refuse to accept, since this would involve him in great additional expense and delay. It is, of course, very different in the case of all kinds of personal or movable property. Here a re-

fusal to accept does not involve the owner in any additional cost.

When a contractor has shown indifference, dishonesty, or incompetency in the execution of his contract, resulting in a material failure to perform, and this work is the building of a structure upon land which becomes part of the real estate, the owner may not only accept and use the structure without compensation to the builder, but, in extreme cases, he may even decline to allow such builder to reconstruct the work, even though he should offer to do so, since the owner thereby has no assurance that a second attempt will result any better than the first.

While the law gives to the owner such remedies as those stated above, he must be careful not to act in such a manner as to imply that he has waived his legal rights in the premises. Thus where a contract is to be performed within a given time, and the time elapses before complete performance, if the owner urges him, or requests him to go on and complete the work, he thereby waives his legal remedies for noncompletion within the time, so far as a *discharge* of the contract is concerned. He may, however, recover damages for the delay.

## REMEDIES FOR BREACH OF CONTRACT.

**50. Results of a Breach of Contract.** When a contract has been broken, or not fully performed, the failure to perform may result either (*a*) in the discharge of the contract as described in the previous article, or (*b*) in a right of action by the injured party for damages sustained, or (*c*) a right of action to enforce specific performance.

The two remedies by which one either obtains damages or enforces specific performance will be discussed in the two following articles.

**51. Damages for Nonperformance.** *The foundation principle of damages is compensation.* Where there has been a partial or complete failure to perform, in accordance with the agreement, the law undertakes to require the party so failing to pay to the injured party such a sum as will cover the actual loss in money value which he has sustained on account of the breach. When the promise was the payment of a certain sum of money, nothing more than this sum with interest can be recovered. Where no decided loss in money value can be shown, the injured party can recover only a nominal sum. That is to say, "a sum of money such as may be spoken of but has no existence in point of quantity."

The leading case in determining the amount of damages which can be collected in the United States courts is that of Hadley v. Baxendale. In this case the court laid down the following rules, which have been followed in all the United States courts.

Where two parties have made a contract which one of them has broken, the damages which the other party ought to receive in respect of such breach of contract should be:

(1) *Such as may fairly and reasonably be considered as arising naturally, i. e., according to the usual course of things, from such breach of contract itself.*

(2) *Such as may reasonably be supposed to have been in the contemplation of both parties at the time they made the contract, as the probable result of the breach of it.*

(3) *Such as arose out of the special circumstances under which the contract was made, where such circumstances were communicated by the plaintiff to the defendant.*

(4) *But, if these special circumstances were wholly unknown to the party breaking the contract, he, at the most, can only be supposed to have had in his contemplation the amount of injury which would arise generally, not affected by any special circumstances.*

It must be remembered that "damages in an action for breach of contract are always by way of compensation, and not a pun-

ishment, hence the plaintiff can never recover more than such pecuniary loss as he has sustained, nor can he recover for great disappointment, nor injury to the feelings, or vexation of mind, caused by the breach."[1]

The party who is injured by a breach of contract is required to make reasonable exertions to render the injury as light as possible, and if he carelessly or indifferently allows the damage to be unreasonably large, such increase falls upon himself.

**52. Distinction between Liquidated Damages and Penalties.**[2] "The parties to a contract not infrequently assess the damages at which they rate a breach of the contract by one or both of them, and introduce their estimate into the terms of the contract. This is perfectly legal, and on a breach the sum agreed upon becomes the measure of damages; as, for example, a stipulation in a building contract that if the building is not completed by a certain day the contractor will pay a certain fixed sum for each day or week or month he is in default, or an agreement in a contract of sale that a certain sum shall be deducted from the purchase price if the quantity is not delivered as agreed. These are called '*liquidated damages.*'

"But the parties in affixing a fixed sum for the nonperformance of his promise by one, or each of them, may have intended not to assess the damages at which they rate the nonperformance of the promise, but to secure the performance by the imposition of a penalty in excess of the actual loss likely to be sustained. And in this case, the amount recoverable is limited to the loss actually sustained, regardless of the sum undertaken to be paid by the defaulter. These are called '*penalties.*'

"The courts will always construe the contract in harmony with the intention of the parties, and without regard to the terms used. If the general effect of the agreement shows that they intended to provide for a penalty they will restrict the recovery to the actual damages incurred although the words 'liquidated damages' are used in the instrument. So, where the parties have used the milder term 'penalty,' courts have

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[1] Breach of promise of marriage is an exception to this rule.

[2] This article is quoted from Lawson on Contracts.

sometimes held that the stipulated sum was, from the nature of the case, to be considered as liquidated damages and recoverable in full. Whether the sum mentioned in an agreement to be paid for a breach is to be treated as a penalty, or as liquidated and ascertained damages, is a question of law, to be decided by the judge, upon a consideration of the whole instrument. Where it is plain that the parties meant the sum fixed to be liquidated damages, the courts will not interfere to frustrate that intention, but, if it be doubtful, upon the whole agreement, whether the sum named was intended to be a penalty or liquidated damages, it will be construed to be a penalty, it being the tendency of the courts to consider the contract as creating a penalty to cover the damages actually sustained by a breach, rather than liquidated damages.

"Subject to the principles stated in the last section the courts have adopted certain rules of construction, in the case of contracts containing promises of this kind; which are:

"1. If the contract is for a matter of certain value and a sum is fixed to be paid on breach of it which is in excess of that value, then the sum fixed is a penalty and not liquidated damages.

"2. If the contract is for a matter of uncertain value and a sum is fixed to be paid on breach of it, the sum is recoverable as liquidated damages. There is 'nothing illegal or unreasonable in the parties, by their mutual agreement, settling the amount of damages, uncertain in their nature, at any sum upon which they may agree.'

"3. Where the contract involves several distinct matters of various kinds, and one fixed sum is stipulated to be paid for any breach, of whatever kind, it is a penalty and not liquidated damages."

**53. Recovery for Imperfect or Incompleted Work.** As stated in Art. 49, recovery can be had under a contract for partial performance, when the contract may be considered as divisible or severable. That is, where a part of the agreement may be entirely fulfilled, while other portions remain unful-

filled. In this case, however, while the party in fault may recover damages for the work done, or goods delivered under the divisible contract, he is always liable for such damages as can be shown to have resulted from his failure to completely perform his agreement.

When the contract can not be considered divisible, but must be looked upon as one and entire, recovery can not be had for anything short of a substantially complete performance. That is to say, a substantially incomplete performance discharges the contract entirely, as stated in Art. 49, and even when the performance is sufficiently complete to prevent discharging the contract, so that recovery can be had for the work done, the owner may still enter a claim for damages for each and every particular in which the performance has been incomplete. Here again if the default is shown to be a wilful neglect or refusal to comply, the law is construed much more severely than for mere oversights.

## SPECIFIC PERFORMANCE.

54. **General Rule as to Specific Performance.** Suits to enforce specific performance can not always be maintained, for actions can be brought at law for such damages as may be shown to have resulted from a breach of the contract, or from a total failure to perform. It has been customary, however, to allow specific performance to be enforced in certain cases where suit is entered in a court of equity, but even in equity specific performance will not be enforced where a payment of damages will put the plaintiff in as good a position as if the agreement had been actually performed. Also if an action for damages would not lie, neither would an action for specific performance. In a case in equity, however, many considerations will be taken account of, in the way of meting out justice to the parties, which could not be considered in a case at law upon the terms of the contract itself.

Where specific performance is ordered by a court of equity, the same court will, if necessary, enforce its decree either by a mandate enforcing the performance named or by an injunction to prevent the doing of the contrary.

Sinces the parties to an engineering agreement can, as a rule, be fully compensated for a failure to perform on the part of either, by a recovery of damages, specific performance can not ordinarily be enforced, and hence this subject will not be further discussed in this connection.

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## DISCHARGE OF RIGHT OF ACTION UNDER A CONTRACT.

55. **The Right of Action.** Upon any breach of a contract there arises in favor of the injured party a legal right of action for compensation. "This right of action can then not be discharged by any payment or performance, or tender of payment or performance, by the promisor, without the consent and acceptance of the promisee; for the promisee, after breach, becomes entitled to the compensation or remedy provided by process of law, and is not bound to accept any tender or offer made in satisfaction of his legal rights." This right of action can only be discharged in one of the following four ways: (*a*) By a Release; (*b*) By an Accord and Satisfaction; (*c*) By a Judgment; (*d*) By Lapse of Time.

(*a*) A Release of a legal right of action consists in a voluntary agreement to discharge a claim, and is only valid when supported by a consideration or when executed under seal. Otherwise it is a mere unsupported promise which binds no one. But a voluntary delivery to the debtor of the evidence of a debt, as of a note or bond, or the destroying of the same, with the intention of discharging the debt, does operate as a release. A release of one of several debtors, jointly, or jointly and severally, liable for the same debt, releases all.

(*b*) Release by Accord and Satisfaction consists in an agreement on the part of the creditor to accept something in satisfaction of his claim, accompanied by the delivery or performance of what has been agreed upon. Here the execution of the agreement is the satisfaction referred to in the phrase "accord and satisfaction," the agreement to accept this being the accord. It should be noted that the right of action is not discharged until this agreement or "accord" is fully executed when "satisfaction" has been rendered.

(*c*) Release by a Judgment. Evidently a judgment obtained through a suit at law in favor of the plaintiff discharges all further right of action against the defendant in the case so adjudicated. His former right is now merged in what is called a contract of record, and this is discharged by the payment of the judgment, or by such satisfaction as can be obtained by process of execution. An adverse judgment against the plaintiff does not discharge the obligation or right of action unless this adverse judgment was rendered on the merits of the case. Of course any judgment may be set aside by the court in which it is rendered, or set aside by a higher court, in which case judgment may be entered in favor of the other party if so ordered, or the parties may be remitted to their original positions.

(*d*) The discharge of right of action through Lapse of Time is in virtue of certain statutory limitations providing that after the lapse of a certain period of time, which is different for different kinds of contracts, the right of action under the contract ceases to exist, and is said to have been discharged by lapse of time. Even in the absence of any statutory provision the courts will not allow a case to be opened on a contract which has long stood as a dead letter. In the common law the period of time which bars the right of action is commonly twenty years. This will apply even to sealed instruments, and for parol agreements this time will be shortened and discharged by payment presumed for shorter periods.

It must not be understood, however, that the courts will

allow either party to an agreement to benefit through lapse of time from a fraudulent contract, although the lapse of an unreasonable time before suit is entered by the defrauded party will have the effect of affirming the contract. In other words, the law reasonably requires that in case of either fraud or breach of contract a prompt recourse to the courts shall be had.

**56. Removal of Statutory Bar to Right of Action.** While statutes of limitation are a bar to a right of action or recovery in the courts, they do not act to extinguish the claim, and hence notwithstanding the time in which suit may be entered has elapsed, the right of action may be revived by (*a*) a promise to pay the debt; (*b*) a subsequent acknowledgment of the debt; or (*c*) a part payment of the debt. In other words, any acknowledgment on the part of the debtor of the existence and legitimacy of the claim, after the right of action has been barred by the statute of limitations, serves to revive the claim for another like period. This acknowledgment of the existence of the debt, in order to serve to revive its legal status is not merely a recognition of the fact of the debt, but must consist in an agreement to pay the debt.

After such a removal of the bar to the right of action, suit may be entered upon the original contract by showing that the claim has been revived by the free act of the debtor. In other words, the debtor has here waived his legal rights of defense, and such a waiving of his rights does not require a consideration to support it, as was shown in Art. 27.

# PART II.

## General Clauses in Engineering Specifications and Accompanying Documents.

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**57. General Considerations.** Nearly all the works designed by engineers and architects are executed by other parties called contractors. The contractor usually buys all the materials and furnishes all the labor required in the execution of the work, as designed, and he agrees to do this within a stated time and for a fixed sum. To insure his doing this satisfactorily certain written documents are prepared and signed by both parties, that is to say, by the man, company, or corporation having the work done and who is to pay for the same, and by the contractor, or the man, company, or corporation who does the work and furnishes the materials.

Standing between these two parties to an agreement is the engineer or architect who has planned the work and who usually superintends its execution and assists in the final settlement between the parties to the agreement. Although paid by the party having the work done he occupies a judicial and not a partisan position and he is expected to act justly and fairly towards both parties.

In order that there shall be no misunderstanding in regard to the intentions of the designer, plans are usually drawn showing the general and detail features of the work, and accompanying these there is a written description of the work, of the materials to be used, of the time and manner of the payments, etc. This document is called the specifications. The drawings and this description are then referred to as the *plans and specifications.*

In order to get open and general competition in doing the work a date is set on which *bids* will be received, and blank *forms of proposals* are prepared by the engineer which can be filled out by the *bidders*, and *notices* or *advertisements* are inserted in the papers and in the engineering journals calling the attention of contractors to this public letting. These and other accompanying documents will be discussed in the order of their sequence in actual practice.

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## ADVERTISEMENTS.

58. **The advertisement** should be as short as possible to contain the necessary information, in order to save expense. It should usually contain the requisite information on the following subjects:

(1) A title indicating the kind of work to be done.

(2) Place, date, and hour of opening the bids.

(3) Person, company, or corporation letting the work.

(4) An adequate description of the work, with especial reference to the kind and quantity (or cost) of work to be done.

(5) Conditions of payment, if these are peculiar.

(6) Instructions as to where to obtain plans, specifications and blank forms of proposals.

(7) Statement as to amount of cash or of certified check or of bond to accompany the bid.

(8) A reservation of the right to reject any or all bids.

(9) Any other peculiar feature, as the letting of the work in parts or as a whole; bids to be received only from experienced contractors, etc.

59. **The Theory of Advertisements.** The object of the advertisement being to secure as large a competition as possible from responsible bidders, it follows that the information conveyed in it should be such as not only to attract the attention

of such parties, but such as would enable them to decide whether or not it would be worth their while to submit a bid. A prominent title indicating the general character of the work would serve to attract the attention of contractors engaged in that line of work. It is a common practice to omit this title, with the result that one is obliged to read nearly the entire advertisement, which is usually printed in small type, before he can learn what the nature of the work is. It is usual also to announce that the proposals or bids which are to be submitted shall be sealed, with the implied understanding that these seals are not to be broken until the bids are opened at the place, date, and hour named. This is for the purpose of preventing collusion and fraud. In other words, the bids are to remain secret and unknown except to the bidders themselves until the hour arrives for opening them. It is also customary to state that these bids or proposals shall be opened in the presence of the bidders, in other words, at an open meeting of the board, or committee, or corporation, or council. To this meeting all persons are free to come and see the bids opened, and to hear them publicly read, with the privilege of taking down the prices named if they choose.

The description of the work included in the advertisement should be sufficient to enable the contractor to decide whether or not it was of such a character as he would be willing to undertake, and also sufficient to enable him to determine the amount of work to be done, and the time required to perform it, as well as the probable approximate cost of the same, and the amount of capital required to successfully prosecute it. The advertisement should also indicate whether or not the work would be let in parts or only as a whole. If it may be let in parts, the advertisement should indicate what the lines of division are, so that one might know what parts he was at liberty to bid upon. It is customary to pay for contract work on monthly estimates of the engineer, reserving from each month's estimate of the worth of materials furnished and work done twenty or twenty-five per cent, until final completion. This

enables the contractor to carry out the work without having the requisite capital to complete the work with his own means. If the conditions of payment are to be other than this, thus making them unusual and peculiar, such conditions should be stated in the advertisement.

Having drawn the attention of contractors to the work and given them the necessary information to enable them to decide whether or not they would wish to submit bids upon the same, it remains to give them such information as may be necessary to enable them to procure promptly the necessary plans and specifications, the blank forms of proposals, and information as to the amount and kind of guarantee which they must submit with their bids to have been considered.

**60. The Guarantee.** The object of the guarantee is always to insure that the successful bidder, or the party who is given the contract, will sign the contract for doing the work and furnish the requisite bond for faithful performance. In other words, this guarantee is simply an assurance of his good faith and honest intentions in submitting his bid, and it is customary to make it consist of cash or the equivalent of cash in the form of a bank check duly certified by the bank as being receivable for the amount stated. This check is to be made payable to the party letting the work, or his agent, and is to be forfeited to such party in case the bidder fails or refuses to enter into a contract for the performance of the work after the award has been made to him. The deposits made by the unsuccessful bidders are, of course, immediately returned to them, and that of the successful bidder is held until he has entered into a contract as above stated, after which it is also returned to the owner. Sometimes it is considered a hardship for the bidders to have to make this cash deposit in submitting their bids, in which case the bidders are asked to furnish a bond or guarantee signed by parties known to be responsible, binding themselves in a stated sum, which sum they agree to pay if the bidder named therein fails to enter into a contract for the faith-

ful performance of the work.[1] Some such guarantee as this should always accompany every bid received in open competition. While this might not be necessary for men of known business integrity, yet in an open competition bids will be received from strangers, and without this kind of an assurance of honest intention the successful bidder will often refuse to enter into a contract on the basis of a bid. In this case the handing in of a bid would involve no financial responsibility, and hence bidders might carelessly submit bids without having taken due precautions to determine the cost of the work, and hence might have made a price altogether too low and one which would involve serious losses on their part if they would undertake to carry out the work for the sum named. In case such a party should receive the award and then after more careful investigation learn that the work could not be performed for the price named in the bid he would decline to enter into a contract and the letting would have to be made over again. This would necessitate readvertising the work, and a considerable delay, in addition to some cost. It is desirable therefore always to require a certain guarantee of good faith which shall accompany the bid itself, and which shall involve considerable loss to the bidder if he declines to enter into a contract in case the work is awarded to him.

**61. Right of Rejection.** It is well always in the advertisement to reserve the right to reject any or all bids, for if this is not done the fair inference is that the contract will be let to the lowest bidder. In some instances, when the work is done under state or city auspices, the law may require that the contract shall be let to the lowest bidder if let at all. In this case the advertisement should state that "the right is reserved to reject all bids," since if parties should not choose to let the work to the lowest bidder their only recourse would be to reject all the bids and advertise the work again. If the parties letting the

[1] Or the agreement may be to pay the difference between the price named and the contract price for which the work may finally be let.

work are not bound by this legal requirement, and if they have reserved the right "to reject any or all bids" in the advertisement, then they are at liberty to let the work to any of the bidders without subjecting themselves to a charge of unfairness. It must be admitted, however, that if the work is not let to the lowest bidder, the parties letting the work subject themselves to invidious criticism, and they should have very good and satisfactory reasons which they are willing to produce in defense of their action, in order to clear themselves from blame before the various parties interested in the letting of the work.

**62. Illustrative Examples.** The following advertisements have been selected from the current journals as fairly embodying in suitable form the requirements as above stated. The student should note the terse and condensed style of these advertisements in which the greatest possible amount of valuable and required information is given clearly but in the least possible space:

CELINA, OHIO, WATER-WORKS—NOTICE TO CONTRACTORS.—Sealed proposals will be received by the trustees of the water-works of the village of Celina, Ohio, up to 8 o'clock P. M. of the 10th day of April, 1895, for furnishing the materials and constructing a system of water-works for said village.

There will be required about 773 tons of cast iron pipe; about 18 tons of special castings; 101 fire hydrants; 76 valves and boxes; brick pumping station and chimney; 2 pumps of a combined capacity of two million gallons per day; 2 boilers; a steel stand-pipe 16 feet in diameter and 125 feet high, etc.

Bids will be received for furnishing any of the materials above or for constructing the works complete. Proposals must be addressed to the Secretary of the Water-Works Trustees, Celina, Ohio, and must contain a certified check or its equivalent, made payable to said secretary in an amount equal to two (2) per cent. of the amount of the bid.

Plans may be seen and specifications and blank form of proposal procured at the office of the trustees, Celina, Ohio, or at the office of the engineers, ———————, Buffalo, N. Y.

The right is reserved to reject any and all bids.

——— ———, Pres.,
——— ———, Sec.,
——— ———,
Trustees of the Water-Works, Celina, Ohio.

———————, Buffalo, N. Y., Engineers.

Proposals for Iron Lathing and Area Gratings.—Office of Building of Library Congress, 145 East Capitol street, Washington, D. C., November 12, 1894.—Separate sealed proposals for furnishing, delivering, and putting in place complete the iron furring and lathing required for the ceilings, partitions, etc., in the first, second, and attic stories, and for the iron gratings and tile lights required for the areas of the Building for Library of Congress in this city, will be received at this office until 2 o'clock P. M. on Tuesday, the 27th day of November, 1894, and opened immediately thereafter in presence of bidders. Specifications, general instructions and conditions, and blank forms of proposal may be obtained on application to this office.

—— ——,
Superintendent and Engineer.

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Notice to Sewer Contractors.—Sealed proposals for building about four (4) miles of pipe sewers in sections 7 and 8 of the Medford sewerage system will be received by the commissioners of sewers at their office until 4:45 P. M., Saturday, March 30, 1895. All proposals must be on forms furnished by the city and accompanied by a check of five hundred ($500) dollars drawn on some national bank, and made payable to the treasurer of the city of Medford. Some approximate quantities are as follows: 20,477 lin. ft. of pipe sewer; 18,081 cu. yds. of earth excavations of all depths; 67 manholes aggregating 578.2 vert. ft. Bricks, pipe, cement, and iron work will be furnished by the city. Plans may be seen, specifications and forms of contract and proposals may be obtained at the office of the commissioners. Each bidder is required to make a statement indicating what sewer work he has done, and to give reference that will enable the board to judge of his business standing; and no bid will be received in case the bidder has not looked the work over on the ground. The commissioners reserve the right to reject any or all bids, if they deem it to the interest of the city so to do.

—— ——,
Chairman Commissioners of Sewers.
—— ——, Engineer, Medford, Mass., March 18, 1895.

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The following advertisements are given as examples of extreme brevity, but since they appeal to a particular class of con-

tractors, accustomed to do such work, they perhaps convey all the information really necessary to give in the advertisement:

TO BUILDERS.—Office of the Light-House Engineer, Eighth District, New Orleans, La., March 20, 1895.—Proposals will be received at this office until 2 o'clock P. M., Wednesday, the 1st day of May, 1895, for furnishing the materials and labor of all kinds necessary for the construction, erection, and delivery of the buildings for the Brazos River Light Station, Texas. Plans, specifications, forms of proposal, and other information may be obtained on application to this office. The right is reserved to reject any or all bids, and to waive any defects. —— ——, Major, Corps of Engineers, U. S. A., Light-House Engineer.

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OFFICE OF ENGINEER, Ninth and Eleventh Lighthouse Districts, Detroit, Mich., March 25, 1895.—Sealed proposals will be received at this office until 3 o'clock P. M. of Monday, the 15th day of April, 1895, for furnishing seven skeleton iron towers for Hay Lake Channel, St. Mary's River, Mich. Plans, specifications, forms of proposals, and other information may be obtained on application to the undersigned. The right is reserved to reject any or all bids, and to waive any defects. —— ——, Major, Corps of Engineers, U. S. A., Lighthouse Engineer.

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OFFICE OF THE COMMISSIONERS, D. C., Washington, D. C., March 28, 1895.—Sealed proposals will be received at this office until 11 o'clock A. M., April 5, 1895, for grading and regulating streets and roads. Blank forms of proposals, specifications and all necessary information may be obtained at this office. —— ——, —— ——, —— ——, Commissioners, D. C.

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U. S. ENGINEER OFFICE, 537 Congress street, Portland, Me., March 4, 1895.—Sealed proposals for dredging in Harrisseckit river, Me., and Bellamy river, N. H., will be received here until 3 P. M., Monday, April 15, 1895, and then publicly opened. All information furnished on application. —— ——, Major Engineers.

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PROPOSALS FOR CONSTRUCTION of dams and shore protections on Upper Mississippi river, between Muscatine, Iowa, and New Boston, Ill. U. S. Engineer Office, Rock Island, Ill., March 16, 1895.—Sealed proposals will be received here until 2 P. M., April 15, 1895, and then publicly opened. All information furnished on application.

U. S. ENGINEER OFFICE, Boston, Mass., Feb. 25, 1895.—Sealed proposals for dredging in "The Narrows," Boston Harbor, Mass., will be received here until noon, April 2, 1895, and then publicly opened. All information furnished on application. —— ——, Lt. Col. Eng'rs.

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## INSTRUCTIONS TO BIDDERS.

**63. Preliminary Information.** A description of many of the general conditions of the work and of the manner of letting it may well be grouped together and printed in connection with the blank forms of proposals. This information is usually placed under the title of "Instructions to Bidders." A fair sample of such preliminary information is given below. All of this information might be, and often is, embodied in the specifications themselves, but they are here separated for greater clearness in the analysis of the various documetns involved in the letting of an engineering contract:

### INSTRUCTIONS TO BIDDERS.

FOR A WATER-WORKS SYSTEM AT THE U. S. MILITARY POST AT FORT RILEY, KAN.

1. No bids will be received for any part of the work herein described from parties who can not show a reasonable acquaintance with, and preparation for, the proper performance of the class of work for which the bid is submitted. Evidence of such competency must be furnished if desired.

2. Proposals must be made on the blank forms to be obtained at this office.

3. Bids will be received as follows:

*First.* On wells and connections complete to the wall of the pump pit. Bidders will state methods which they propose to use in sinking wells.

*Second.* On boiler, coal and dwelling house, pump pit and reservoir, with roof complete.

*Third.* On all machinery including boilers, furnaces, stack, concrete floor in boiler and coal house, pump, connections, suction and discharge pipes to the outside of pump pit wall, benches, tools, etc. Bidders must state what kind of pump they propose to furnish.

*Fourth.* On the pipe system, complete with hydrants and valves, and to include the following items:

(*a*) Price per foot for eight (8) inch mains.

(*b*) Price per foot for six (6) inch mains.

(*c*) Price per foot for four (4) inch mains.

These items are introduced to cover any slight variations in lengths over or under the amounts herein specified, and contractors hereby agree to such extension or reduction at the prices named.

Bidders may make in addition to the above a bid for the entire work complete.

4. Each proposal must be accompanied by a written guaranty in the sum of $2,000 (executed strictly in accordance with the printed instructions, and upon the blank forms furnished under this circular), signed by two responsible persons, to the effect that if the proposal is accepted within sixty days from the date of the opening of the proposals, the bidder will, within ten days after being notified of such acceptance, enter into a contract and give bond with good and sufficient sureties, and that in case of failure of the bidder to enter into contract and give bond, they will pay the difference between the amount of his bid and the amount for which contract may be made with another party.[1]

5. The amount of the penalty of the bond to be furnished by the contractor will not be less than one-tenth nor more than the full sum of the consideration of the contract.

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## FORMS OF PROPOSALS

**64. The Object of Blank Forms of Proposals.** In order to insure that all the bidders shall submit their proposals on exactly the same items and estimate prices in the same units, it is necessary to prepare printed blank forms to be used by all the bidders, these forms being complete in all respects except the prices and the names of the bidders. So important is it to have the bids exactly comparable in all respects that it is customary to reject all bids not made out on these printed forms as well as all bids which, though made on the printed forms,

[1] In place of this it is more common to require the bid to be accompanied by a certified check (or cash) for a specified sum, to be forfeited in case the bidder fails to enter into contract if the work is awarded to him.

have changed the conditions of the same in any particular, either by erasures, interlineations, or additional conditions. If the bidder desires to submit a proposition in a different way or with other conditions than those stated in the printed form he should submit his bid on the printed form without correction or change and then append to his bid an auxiliary paper embodying such changes as he would wish to make, and the price he would submit if these changes were agreed to. In this way he complies strictly with the requirements by submitting a bid which is regular in every respect, and in addition submits what is practically another bid on a modified basis. While the modified bid is, of course, irregular, and would not be considered in conjunction with the regular bids, it would give to the parties letting the contract the information which he desires them to have, and states the modifications which he would agree to if the bid were let to him on the basis of his formal and regular proposal. The work might then be let to him on the basis of his valid proposal, with the expectation of making the terms in the final contract in accordance with the bidder's amended proposition. If the parties letting the contract, however, should not choose to do this, the bidder would still be bound by his formal or regular proposal. The importance of making the bids strictly comparable in every respect is so very essential to fair and intelligent treatment of the bidders themselves, and so necessary in order to determine which is really the lowest bid, that the practice of preparing and supplying such blank forms of proposals should always be followed.

**65. Manner of Letting the Work.** Before such forms can be prepared, however, several questions must be decided, among which are the following:

1. Shall the work be let as a whole, or shall it be let in parts.

2. Whether let as a whole or in parts, shall bids be received for fixed sums for the whole or for the several parts, or shall they be received on a basis of certain suitable units of measurement. As, for instance, per cubic yard, for earth work, per perch for masonry, per pound for iron work, per square yard

for street paving, per mile for railroad rails and ties, or per lineal foot for water pipe or sewers, etc.

3. Shall the work be let in such a way as to involve the payment of a bonus or additional sum for the performance above that required, and a corresponding reduction in price for a failure to meet the requirements.

4. Shall the work be let for a certain price for the original construction, and a certain price per annum for maintenance for a given period.

5. Shall the contractor be required to furnish all materials and perform all the labor, or shall the principal purchase a portion or all of the material and turn it over to the contractor for use in the construction of the work.

**66. Contract Let as a Whole or in Parts.** Some of the considerations in favor of letting work as a whole rather than in parts are:

(*a*) By this means one man or company alone is responsible for the faithful performance of the work both as to quality and as to time. This prevents a division of responsibility which is always bad, and in the case of carrying out contract work is often the cause of failure to have the work completed within the time specified, without being able to locate the responsibility for such delay. Where there are several contractors upon the same piece of work, each may so stand in the way of another that the work may be greatly delayed, and yet each one of the several contractors may have a reasonable defense which would shield him from personal liability.

(*b*) When there is but a single contractor the business is concentrated so that the work of the engineer or of the inspectors is greatly lessened from having to deal with one man instead of many separate contractors.

(*c*) When several contractors are engaged upon the same work it is difficult for them so to plan their parts, in time, as to avoid a certain amount of delay where the work of one is dependent upon antecedent work of another. When the work

is done by a single contractor he can arrange to avoid such delays as are almost necessarily incident to the working of several contractors in sequence.

(*d*) When the work is such as is commonly let in a single contract, or in other words, when bids can be received from parties who have been accustomed to carry out all parts of such a work, it is usually more economical to let the work in a single contract than it is to let it in parts. In the former case there is but one man to reap a profit from the construction, whereas if let in parts, each contractor must, of course, make his estimate in such a way as to allow himself a reasonable profit.

Some of the arguments in favor of letting the work in parts are:

(*a*) The project may involve constructions of such different kinds as to make it impracticable for one contractor to undertake the entire work. In this case the letting in parts is necessary to a skillful performance.

(*b*) Where there are local parties who are competent to execute portions of the work, but not the whole, and who are anxious to bid upon such portion, it may be wise to let the work in parts provided it is reasonably certain that competitive bids can be received on all the parts. Even in this case it is desirable also to receive bids upon the whole work, so that when the bids are opened it will appear which is the more economical method of letting. Even when it is reasonably certain in advance that the contract will be let as a whole it is often wise to receive bids on the parts in order to satisfy local demands, and to avoid invidious criticism and public detraction. This is especially true in the case of public works, if the local bidders who wish to submit proposals on parts of the work, but who would be incompetent to bid upon the whole, are shut out by receiving bids only upon the entire project.

**67. Contract Let for a Fixed Sum or per Specified Units.** When the work to be performed under a contract is perfectly definite as to quantity, it is best to let the contract for a fixed

sum. When either the quantity of work to be done or the quality or kind of material to be encountered, as in excavations, is more or less unknown and indeterminate, it is necessary to let such parts of the work at least, in terms of some suitable unit of measurement. Thus in the case of excavation, the kind of material which will be encountered is always more or less uncertain, and the quantities to be moved are usually undetermined in advance. In various other lines of work, also, the exact quantities are not measured or computed in advance of the construction, so that in all such cases it is necessary to let the work per unit of measure. It is often wise, however, to assume a certain definite amount of work of each kind to be performed, and let the contract for a fixed sum on the basis of this assumption, providing for variations from these amounts in the blank form of proposal by requiring the bidder to state not only a fixed sum for the assumed total, but also a price per unit of measure, in accordance with which the quantities assumed as the basis of the bid may be either increased or diminished, it being understood, however, that the quantity stated is approximately the amount of work to be performed. In this way it becomes known in advance about what the work is to cost, and if the quantities are changed somewhat these changes do not become a source of contention between the parties.

In choosing the units of measure which shall serve as the items to which prices are to be affixed by the bidders, it is necessary to select and describe these units in such a way that they can not be misunderstood; thus in masonry it is better to use the cubic yard as a unit rather than the perch, since this latter has different values in different localities. Also it should be clearly defined in the proposal itself in what way these measurements should be taken, as, for instance, in masonry, whether all openings should be excluded, and in tunnel excavation that the measurement should include only the material excavated inside the given sectional boundaries, and in water pipe on which bids are received per foot in length for the various sizes,

that the measurements should be taken on the center lines of such pipes, after they are laid, etc. Also in the case of the furnishing of materials, machinery, and appliances, the printed proposal should indicate where the material is to be delivered and whether or not the machinery is to be erected. The failure to make the proposal clear in these and other minor particulars is often the cause of serious disagreements, provoking delays, and sometimes of considerable expense.

**68. Contract Involving a Specific Performance.** When machinery is purchased on the basis of a specific performance, as in the case of pumping engines, steam boilers, steam ships, and the like, where a specific performance is made the basis of the contract price, it is customary and proper to provide for specific additional sums for stated percentages of excess of performance over and above that which forms the basis of the bid, and also for stated deductions from the contract price for given percentages by which the performance fails to meet the standard. In this way the contractor is fairly paid for accomplishing more than he agreed to, and the purchaser obtains a fair reduction in price for any failure to reach the agreed standard. When a specific performance is made the basis of a contract without these agreed premiums and discounts, the purchaser is at liberty to refuse to accept the work at any price, in case of even a partial failure to meet the specified requirements; while, on the other hand, if the contractor has far exceeded the specifications, he gets no benefit whatever for the enhanced value of the product. A specific performance, therefore, when made the basis of the acceptance of a piece of contract work without these provisions for premiums and discounts is a very onesided and unfair contract, and its use should be discouraged by engineers.

In all cases where a specific performance is made the basis of a contract price, the conditions of this performance should be so clearly stated in the specifications, and the nature of the tests to determine this performance so distinctly described that

no misunderstanding can arise when the time comes for making these tests. These descriptions belong in the specifications rather than to the proposals.

**69. Contract Including Maintenance.** In the case of street pavements, especially where the material is new or untried, it is common to require the contractor to maintain it for a given period, at a stated price per annum. In this case this maintenance price must also be provided for in the proposal, as well as the price charged for first cost.

**70. Contract for the Work Only.** It is often wise for the principal to purchase materials himself which shall be used by the contractor in the carrying out of the work. Thus the principal may wish to use a particular kind or quality of material which he does not wish to describe specifically in the specifications, or which, if described, he can not well assure himself that the contractor will furnish. Especially is this the case with such materials as can not be clearly identified by ordinary methods of inspection; as, for instance, various kinds of paints, cement, iron and steel, paving brick, besides a great number of specialties in the line of manufactured articles and machines. Or, the contractor may not be able to purchase this material on as favorable terms as the principal, because of the greater risk involved in the sale of this material when the contractor must be looked to for payment. Thus, when the bidders are informed that the principal will furnish materials which would otherwise cost the contractor large sums of money, many contractors of small means would be encouraged to bid upon the work, who otherwise would not be able to handle it. For these and other reasons, therefore, it is frequently wise for the principal to purchase the material and turn it over to the contractor for use in the work.

**71. Proposal for Building a Dam, Spillway, Levee, Outlet Tunnel, and Overflow Chamber.**

To the First New Mexico Reservoir and Irrigation Co.,
Roswell, New Mexico.

*Gentlemen:*—The undersigned propose to do all the work and furnish all of the material in accordance with the printed

form of contract and specifications, a copy of which is herewith annexed, and bind———, on the acceptance of this proposal, to enter into and execute a contract in the form of said enclosed specifications and contract for the execution of said work at the prices named below, to wit:

*Excavation:*

(*a*) Earth, including all forms of soil, or clay, per cubic yard———.

(*b*) Gravel and sand, including all forms and combinations of these materials, per cubic yard———.

(*c*) Loose rock in open cut, including all kinds of loose rock not requiring blasting, per cubic yard———.

(*d*) Solid rock in open cut, including all kinds of rock requiring blasting, per cubic yard———.

(*e*) Rock in tunnel, including all tunnel work to the outer line of the lining wall, if such be required, otherwise to the lines of the drawings, per cubic yard———.

*Fill:*

(*a*) Earth, clay, gravel or sand, not rolled, per cubic yard ———.

(*b*) Same materials spread in courses and rolled dry, per cubic yard———.

(*c*) Same materials spread in courses, dampened and rolled, per cubic yard———.

(*d*) Same materials spread in courses, pulverized, harrowed, wet down and rolled thoroughly, per cubic yard ———.

(*e*) Clay and gravel mixed in layers, harrowed, wet down and rolled thoroughly (clay puddle), per cubic yard ———.

(*f*) Loose rock dumped or thrown in as in temporary dam, per cubic yard———.

(*g*) Rip rap laid on face of dam, per cubic yard———.

(*h*) Facing rock laid dry with close joints for distance of 4 inches from surface and rammed, per cubic yard ———.

*Masonry:*

(*a*) Rubble masonry laid in Portland cement mortar, as described, per cubic yard———.

(*b*) Masonry lining of tunnel, as described, per cubic yard, actual volume———.

(*c*) Dimension stone masonry, laid in Portland cement mortar, as described, per cubic yard———.

Enclosed is a certified check for five hundred dollars; which sum is to be forfeited to the First New Mexico Reservoir & Irrigation Co. if the party or parties making this proposal fail

to enter into contract, with approved securities, within fifteen days after the contract is awarded to said party or parties.

Respectfully,

(Signature and address of contractors.)

—— ——.

—— ——.

St. Louis, Mo., ——, 1890.

Note.—Each bid shall be placed in a sealed envelope addressed to "——, President First New Mexico Reservoir & Irrigation Co.," care of "——, Consulting Engineers, ——, St. Louis, Mo.," and shall be indorsed "Proposal for building Dam, etc."

The First New Mexico Reservoir & Irrigation Co. reserves the right to reject any or all bids.

J. & F.

72. **Proposal Bond.** In lieu of a cash deposit accompanying the bid as a guarantee of good faith and of intention to enter into contract, if the same be awarded to the party, a bond may be received, duly signed and certified, which will insure either the signing of the contract, or the payment of such damages as may result from a failure to sign. These damages would usually be measured by the difference between the amount named by the party furnishing the bond, and the sum for which the contract might finally be let, and this is usually named as the amount of the forfeiture under the bond. It is the usual custom of the United States Government to require a bond of this sort rather than a cash deposit. It is evidently a less hardship upon the contractor to furnish such a bond. The following is the form of this document as used by the United States Government:

Proposal Bond or Guaranty.

We, —— ——, of ——, in the state of ——, and —— ——, of ——, in the state of ——, hereby guarantee and bind ourselves and each of us, our and each of our heirs, executors and administrators, to the effect that if the bid of —— —— herewith accompanying, dated ——, 1894, for furnishing all materials and labor, and constructing the power house and office building for the 800-ft. lock at St. Mary's Falls canal, shall be accepted, in whole, or in part, within sixty (60) days from the date of the opening of proposals, the said bidder—, —— ——, will, within ten (10) days after being notified of such accept-

ance, enter into a contract with the United States in accordance with the terms and conditions of the advertisement, and will give bond with good and sufficient sureties for the faithful and proper fulfillment of the same. And in case the said bidder— shall fail to enter into contract within the said ten (10) days with the proper officer of the United States, and furnish good and sufficient bond for the faithful performance of the same according to the terms of said bid and advertisement, we and each of us hereby stipulate and guarantee, and bind ourselves and each of us, our and each of our heirs, executors and administrators, to pay unto the United States the difference in money between the amount of the bid of the said bidder—, and the amount for which the proper officer of the United States may contract with another party to furnish said materials and labor and construct the power house and office building as specified, if the latter amount be in excess of the former, for the whole work covered by the proposal.

WITNESSES:

—— ——, —— —— [SEAL]
—— ——. —— —— [SEAL]

Dated ——, 1894.

Executed in triplicate.

JUSTIFICATION OF GUARANTOR.

STATE OF ——, } ss
County of ——. }

I, ——, one of the guarantors named in the within guaranty, do swear that I am pecuniarily worth the sum of forty thousand dollars, over and above all my debts and liabilities.

[Signature of guarantor] —— ——.

Before me,
[Signature of officer administering oath, with seal, if any.]
—— ——.

STATE OF ——, } ss.
County of ——. }

I, ——, one of the guarantors named in the within guaranty, do swear that I am pecuniarily worth the sum of forty thousand dollars, over and above all my debts and liabilities.

[Signature of guarantor] —— ——.

Before me,
[Signature of officer administering oath, with seal, if any.]
—— ——.

CERTIFICATE.

I, —— ——, do hereby certify that —— —— and —— ——, the guarantors above named, are personally known to me, and that, to the best of my knowledge and belief, each is pecuniarily

worth, over and above all his debts and liabilities, the sum stated in the accompanying affidavit subscribed by him.

[Signature of certifying official] ——— ———.
U. S. ENG. CORPS.

NOTE.—The certificate may be given separately as to each guarantor, and modified accordingly.

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## ENGINEERING SPECIFICATIONS.

73. **Engineering Specifications Defined.** Engineering specifications consist of a series of specific provisions, each one of which defines and fixes some one element of the contract. These clauses relate, in general:

*First.* To the work to be done.

*Second.* To the business relations of the two parties to the contract.

In the first sense, the specifications supplement and explain the plans (if there be any) and define the character of the materials and the methods to be employed on the work, or, if unaccompanied by plans, they embody the principles and rules in accordance with which the plans must be drawn and the work executed. In this sense the specifications enable the bidder to estimate the cost of the proposed work and after the contract is let they serve as the rules of inspection and acceptance of such work.

In the second sense the specifications define the rights and duties of the two parties to the contract to each other and embody proper provisions for changes in the plans, and for the settlement of disputes which may arise; they also describe the conditions of payment, acceptance, etc. etc.

74. **Classes of Specifications.** There may be said to be three general classes of engineering specifications:

(*a*) Specifications accompanying complete detail plans.

(*b*) Specifications accompanying a general plan only.

(*c*) Specifications unaccompanied by any plan, and commonly known as general specifications.

All of these classes of specifications are in common use and each has its own particular sphere of usefulness.

(*a*) Thus, when the design is novel, or when the engineer wishes a particular design carried out, he usually prepares full detail plans, or drawings, showing how all parts of the proposed work shall be done.

In the case of public works, also, when the law requires the contract to be let in open competition, and also specifies that it shall be let to the lowest bidder, it is almost necessary to prepare full detail plans in order to avoid an inadequate or inferior design being put into competition with better ones, and, from its diminished cost, receiving the contract.

(*b*) If the engineer can limit the bidders to a selected class of reliable contractors, who have reputations to lose if they should do inferior work, he may prepare very general plans only and allow the contractor to make the details to suit himself, in accordance, however, with certain specific requirements as given in the specifications, and subject to the approval of the engineer.

(*c*) If the engineer is indifferent as to even the general design, provided the finished work answers equally well certain prescribed demands, as given in a set of general specifications, he may not prepare any plans whatever, but leave the contractor (who must now also be chosen by the engineer or only responsible parties allowed to bid) to use any design he may choose, such designs to be submitted, however, with his bid, and this, together with the general specifications to form the basis of the contract.

75. **General and Specific Clauses.** Any specification may be said to be composed of two kinds of clauses, general and specific.

All those clauses which relate to the business portion of the contract, or which go to define the relations of the parties to the civil contract as a business proposition, may be said to be the general clauses.

All those clauses which are descriptive of the engineering

or structural features of the design, either as explanatory of the plans, or of the materials to be used, or of the methods to be employed, may be called the specific clauses.

Since the general clauses are common to all kinds of specifications, they will be discussed first.

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## THE GENERAL CLAUSES IN SPECIFICATIONS.

76. **The General Clauses in Specifications** may relate to any or all of the following subjects:

(1) Time of commencement, rate of progress, and time of completion of the work.

(2) As to the character of the workmen to be employed.

(3) Suitable appliances to be used.

(4) Monthly estimates of work done and payments to be made.

*(5) Provision for inquiring into the correctness of the monthly estimates.*

(6) Reserving a certain percentage as a repair fund, for a stated period after completion.

*(7) Conditions of the final estimate.*

*(8) Engineer's measurements and classifications final and conclusive.*

(9) Determination of damages sustained by failure to complete the work within the time agreed upon or as extended.

(10) The discharge of unpaid claims of workmen and material men.

(11) No claims for damages on account of suspension of work.

(12) No claims for damages on account of delay.

(13) No claims on account of unforeseen difficulties.

(14) Protection of finished work.

(15) Protection of property and lives.

(16) Protection against claims for the use of patents.

(17) Assignment of contract.

(18) Contractor not released by subcontracts.

(19) Abandonment of contract.

(20) Cancellation of contract for default of contractor.

(21) Workmen's quarters and other temporary buildings.

(22) Cleaning up after completion.

(23) Removal of condemned material.

(24) Relations to other contractors.

(25) Provision for drainage.

(26) Provision for public traffic.

(27) Contractor to keep foreman or head workman and also copy of plans and specifications on the ground.

(28) Cost of examination of completed work.

(29) Faults to be corrected at any time before final acceptance.

(30) Surveys, measurements and estimates of quantities not guaranteed to be correct.

(31) The contract subject to interpretation and change by the engineer.

(32) Settlement of disputes.

(33) Extra work.

(34) Definition of "engineer" and "contractor."

(35) Documents composing the contract.

(36) Meaning understood.

(37) Provision for arbitration.

(38) No waiver of legal right.

77. **Explanatory Note.** In all that follows on the subject of specifications, after explaining and discussing a given subject, one or more illustrations will be given in solid type, from actual specifications, together with the initials of the author. The full name and professional engagement of the author can then be found by referring to the *Key to Personal References*, page vii. In general the latest practice only of the engineers quoted in this way will be cited. It must also be understood that in every case the gentlemen so quoted have themselves selected the sample specifications used and have consented to such use.

**78. Time of Commencement, Rate of Progress, and Time of Completion of the Work.** It is usual to make the time of commencement of the work as soon after the signing of the contract as is thought practical, as, for instance, ten, fifteen or thirty days, depending on the character of the work.

The rate of progress is specified in order to give the engineer authority for canceling the contract if the rate of progress is such as to indicate that the contractor will certainly be unable to complete the work on time, or at all. Thus he may be obliged to abandon the work altogether, or he may choose to do so, in which case, if rate of progress is specified, the parties of the first part need not wait for the full time for completion to arrive before being able to take the work from the hands of the contractor and complete it by hiring the labor and purchasing the materials, or by reletting it to another contractor.

The time of completion is nearly always stated, and while the time allowed should be ample it should be only such as is required when a reasonable degree of diligence is exercised on the part of the contractor.

If, for any sufficient reason, the contractor is delayed in his work, for reasons beyond his control, the time of completion is usually extended by the principal by a corresponding length of time, and then this extended period fixes the required or specified date of completion.

And the said party of the second part further agrees that he will commence the work herein contracted to be done within twenty days from the date of this contract; that the rate of progress of his work shall be such as, in the opinion of the engineer, is necessary for completion within the time herein specified, and that he will so conduct the said work that on or before July 1, 1899, the whole work covered by this contract and specification shall be entirely completed. A. F.

**79. As to the Character of the Workmen to be Employed.** In order to secure good work it is necessary to employ skilled workmen. The engineer must therefore have some control over the character of the labor employed by the contractor. This is obtained by specifying that only skilled labor shall be employed and giving to the engineer the power of discharge

over any laborer, mechanic, foreman or superintendent employed by the contractor on the work. It is also customary to provide that this power shall extend to cases of disobedience of instructions, impudence to engineer or inspectors, drunkenness, etc., as shown in the following illustration:

And the said party of the second part further agrees to employ only competent, skillful men to do the work; and that whenever the engineer shall inform said party of the second part in writing that any man on the work is, in his opinion, incompetent or unfaithful or disorderly, such man shall be discharged from the work, and shall not again be employed on it.

A. F.

**80. Suitable Appliances to be Used.** If not prevented by a special clause in the specifications, contractors who are unprovided with suitable mechanical appliances for doing the work properly will often undertake to perform the work with cheap and inadequate means, which would necessarily result in faulty construction, or in delaying the work. It is customary, therefore, to prescribe that all appliances shall be suitable and adequate to the purpose, and subject to the approval of the engineer. It is not wise, however, to specify particular methods or means of doing the work, since if for any reason a partial failure should result, the contractor will endeavor to obtain personal release by charging failure to the specified appliances or methods. A specification like the following is therefore recommended:

The contractor is to use such methods and appliances for the performance of all the operations connected with the work embraced under this contract as will secure a satisfactory quality of work and a rate of progress which, in the opinion of the engineer will secure the completion of the work within the time herein specified. If, at any time before the commencement, or during the progress of the work, such methods or appliances appear to the engineer to be inefficient or inappropriate for securing the quality of the work required or the said rate of progress, he may order the contractor to increase their efficiency or to improve their character, and the contractor must conform to such order; but the failure of the engineer to demand such increase of efficiency or improvement shall not relieve the contractor from his obligation to secure the quality of work and the rate of progress established in these specifications.

A. F.

**81. Monthly Estimates of Work Done and Payments to be made.** It is customary, in all kinds of engineering construction, for the engineer in charge to estimate at the end of each month the quantity of material furnished on the ground and of work done. These estimates are approximate only and serve as a basis for making monthly payments to the contractor. It is customary to reserve from ten to twenty-five per cent. of these monthly estimates until the final completion of the work. By means of these monthly payments the contractor is enabled to carry on the work to final completion with a much smaller capital than would be required if no payments were made until the work was finished. The percentage reserved from the monthly payments is intended to serve as a guarantee of final completion, and as a fund to draw upon when the time of final settlement arrives, for the payment of damages resulting from the work not having been performed within the specified time, or for other purposes as indicated subsequently in these general specifications. In the matter of payment for materials furnished, but not incorporated finally into the work, it is usually considered safe to include in the monthly estimates all materials delivered, either upon the ground, that is to say, along the line of the work, and subject to the inspection and control of the engineer, and also to pay for materials and machinery furnished and stored where they are under the control and subject to the inspection and approval of the engineer. Of course no material would be included in these monthly estimates which had not been duly inspected and accepted.[1] The following is a common form for this specification:

In order to enable the said contractor to prosecute the work advantageously, the engineer shall, once a month, on or about the last day of each month, make an estimate in writing of the amount of work done, and materials delivered to be used in the work,[1] and of the value thereof, according to the terms of this contract. The first such estimate shall be of the amount or quantity and value of the work done and materials delivered since the party of the second part commenced the performance

[1] If payment is made upon materials furnished then it should be specifically stated that all such materials become the property of the party of the first part as soon as delivered and accepted.

of this contract on his part. And every subsequent estimate (except the final one) shall be of the amount or quantity and value of the work done since the last preceding estimate was made. And such estimates of amount and quantity shall not be required to be made by strict measurement or with exactness; but they may, at the option of the engineer, be approximate only.

Upon each such estimate being made the parties of the first part will pay to the party of the second part the following proportions or percentages thereof, to wit:

85 per cent. thereof up to and until such time as the total estimated value of the work done and materials delivered shall amount to $1,000,000.

90 per cent. thereof after the total estimated value of such work and materials delivered shall have amounted to $1,000,000, until the party of the first part shall have fully and completely performed this contract on his part. A. F.

**82. Provision for Inquiring into the Correctness of the Monthly Estimates.** The monthly estimates made by the engineer acting as the agent of the party of the first part, may be held to be binding upon this party, in case he has either made a mistake in the quantity of work done, or material furnished, or has entered into collusion with the contractor and rendered false returns. Since the engineer is the agent of the party of the first part, his acts would bind his principal, after payment had been made on the same, if it were not expressly provided that the party of the first part shall not be estopped or prevented from determining by other means the amount of work done and material furnished. In other words the party of the first part should not necessarily be bound by either the monthly or final estimates rendered by his agent, and which are intended to serve as the basis of payment. It is understood, of course, that the contractor also has this privilege of inquiry and proof of the correctness of the estimates.[1] In New York city clauses like the following are common:

And it is hereby expressly agreed and understood by and between the parties hereto that the said parties of the first part,

[1] If the contractor is precluded from going back of the engineer's certificate or decision, then the owner should also be bound by the same, and in this case this clause would probably not be sustained by the courts. The engineer is now an arbitrator and as such his decisions must bind both parties or neither.

their successors and assigns, shall not, nor shall any department of the city of New York, be precluded or estopped by any return or certificate made or given by any engineer, inspector or other officer, agent or appointee of said aqueduct commissioners, or of said parties of the first part, under or in pursuance of anything in this agreement contained, from at any time showing the true and correct amount and character of the work which shall have been done and materials which shall have been furnished by the said party of the second part, or by any other persons under this agreement. A. F.

83. **Reserving a Certain Percentage as a Repair Fund, for a Stated Period after Completion.** In order to provide for inherent defects in the work which may not appear on the surface, or until after the construction has been in service for some time, it is often desirable to retain a portion of the total cost of the work for a specified period of time, on which sum the party of the first part is authorized under the specifications to draw for the repairing or correcting of any and all faults or defects which may become apparent by use within the specified period. It is usual, however, to give the contractor the privilege of making such repairs under the direction and subject to the approval of the engineer, in place of having the engineer make such repairs and charge them against the reserve fund. This clause may read as follows:

The contractor hereby further agrees to make all the needed repairs on the said work during a period of —— months after its final completion; and he hereby further agrees that the party of the first part is authorized to retain out of the moneys payable, or to become payable, to him, under this agreement, the sum of five per cent. on the amount of the contract, and to expend the same, or so much thereof as may be required, in making the aforesaid repairs to the satisfaction of the engineer, if within three days after the delivery or mailing of a notice in writing to the contractor, or his agent or attorney, he or they shall neglect to make the aforesaid needed repairs; and he hereby further agrees to be responsible for any accident that may occur on account of the defective condition of the work.

E. A. F.

84. **Conditions of the Final Estimate.** If, in the opinion of the engineer, the contractor has completed his work in all respects in accordance with the terms of the contract, he should

proceed with due diligence to make the final estimate of all quantities in the several clauses, and to certify to his principal the amount of money due to the contractor, and also the amounts which should be held in reserve under the various clauses of this character in the specifications. The party of the first part thereupon should immediately pay to the contractor such moneys as are legally due him, provided this party is satisfied that the final estimates submitted by the engineer are correct. If this party should have any doubts on this point he should be at liberty, under the specifications, to inquire further into the correctness of such estimates. This portion of the contract may be stated as follows:

It is further mutually agreed that whenever this contract, in the opinion of the engineer, shall be completely performed on the part of the contractor, the engineer shall proceed with all reasonable diligence to measure up the work, and shall make out the final estimates for the same and shall certify the same. The party of the second part will then, excepting for the cause herein specified, pay to the contractor within —— days after the execution of said certificate the remainder which shall be found to be due, excepting therefrom such sum or sums as may be lawfully retained under any of the provisions of this contract: Provided, that nothing herein contained shall be construed to affect the right hereby reserved, to reject the whole or any portion of the aforesaid work, should the said certificate be found to be inconsistent with the terms of this agreement, or otherwise improperly given. E. A. F.

**85. Engineer's Measurements and Classifications Final and Conclusive.** In order to avoid disputes as to both the quantity and the quality of the work done, it is customary to specify that the measurements and classifications of the engineer shall be final and conclusive and binding upon both parties. This is a very important provision and places a great responsibility upon the engineer, while it binds at the same time the two principals to the contract and forces them to submit to the engineer's decisions, except as some special provision such as that stated in article 81 allows one or both of the parties to examine into the correctness of the engineer's estimates. As a matter of course either party is always at liberty to ex-

amine questions of fact and, so far as it is practicable, to remeasure quantities at subsequent times. Either party would be at liberty in case of a suit at law to have such quantities remeasured to determine such question of fact, but so far as the classification of the material is a matter of opinion on the part of the engineer, and so far as measurements of quantities have become impracticable at a subsequent period, to this extent a clause such as is here proposed binds absolutely both parties to the contract. Neither party now has any release from the decision of the engineer, except on one of two grounds:

*First.* Either party may bring a suit in equity, in which case the terms of the contract are not made the basis of the suit; or

*Second.* Either party may enter a plea of fraud on the part of the engineer, which, if sustained, would, of course, vitiate the decisions of such engineer. Neither of these grounds offers much encouragement to either party. A case could not be sustained in equity contrary to the terms of an expressed written agreement, except it could be shown that gross and violent injustice had been worked by a strict compliance with its terms. Neither is it desirable in a civil suit to enter a plea of fraud, since this is very difficult to maintain, and can only be maintained by proving the moral depravity of the engineer. A clause such as the following, therefore, if incorporated in a contract and agreed to by both parties, places both parties absolutely at the mercy of such engineer, and the contractor should never submit to it, if he has reason to suppose that the engineer is likely to act unfairly toward him under the authority thus granted to him. As a rule, however, this confidence which is reposed in the engineer by both parties to the contract is not misplaced. Although the engineer is paid for his services by one of the parties to the contract, he understands that his position is a judicial one, and not that of an advocate or partisan, and that it is his business to see that justice is done to both of the parties. The clause usually reads as follows:

All the work under this contract shall be done to the satisfaction of the engineer, who shall in all cases determine the amount, quality, acceptability and fitness of the several amounts

of work and materials which are to be paid for hereunder, and shall decide all questions which may arise as to the measurement of quantities and the fulfillment of this contract on the part of the contractor, and shall determine all questions respecting the true construction or meaning of the plans and specifications, and his determination and decision thereon shall be final and conclusive, subject only to revision by arbitration as provided under art. —.[1] R. H.

**86. Determination of Damages Sustained by Failure to Complete the Work within the Time Agreed upon, or as Extended.** It is seldom that a specific performance of any contract can be enforced. In other words, either of the parties to almost any civil contract is at liberty to break the same, or fail to carry it out, for which failure, however, the law provides that the party breaking the contract shall pay a penalty. The amount of this penalty usually remains to be ascertained after the contract has been broken, and when the time of settlement arrives. The legal remedies for breach of contract are given in arts. 49–53. It is sufficient to remark here that in determining the amount of the damages, the law will only allow the actual proven damages to be collected, and always discourages any constructive or conventional or arbitrary estimate of such damages. In other words, the damages are the compensation to the injured party, requisite to repay him for his loss, which can be traced directly to the breach of contract.

While damages to the extent of the actual injury sustained can always be recovered, by a suit at law, in the case of a breach of contract, it is customary in the writing of engineering specifications to insert one or more clauses defining the amount of the damages which it is agreed by the parties will be sustained in case of certain specific failures to carry out the contract; and since these failures are assumed to be on the part of the contractor, and since money is usually due him from the other party, it becomes possible, in this case, to remunerate the injured party by withholding a certain sum of money from the contractor who is guilty of the breach of contract. If a specific

[1] Here should be inserted a clause like the following: "And such estimate and decision shall be a condition precedent to the right of the contractor to receive any money or compensation for anything done or furnished under this agreement."

agreement to this effect be entered into by the parties, in advance, the compensation for the injury done because of a specific breach of the contract may be recovered by simply withholding such a sum from the contractor and paying over to him in final settlement the remainder. Because, therefore, of the facility with which such a settlement can be accomplished, and also to further provide against such a contingency arising by furnishing to the contractor a sufficient motive to prevent such specific breaches, and furthermore, in order to avoid a suit at law for the recovery of such compensation, it has become customary to insert what is commonly called a "penalty clause."[1]

While recovery can be had by a suit at law for the actual damages sustained for any breach of the contract, either with or without a specific clause to this effect, the penalty or damage clause in the specifications usually refers to one or more specific kinds of breach of contract, the more common one being that of failure to complete the work within the time agreed upon. The object of a penalty clause covering this particular kind of breach of contract is rather to insure completion of the contract within the time specified than to recover damages for a failure to do so. For this reason it has been commonly supposed if a heavy penalty were provided for a failure of this kind, it would serve as a strong motive to the contractor to hasten the work. This being the object of such a clause it has been common to specify a penalty or damage of so many dollars per day for each and every day elapsing after the date agreed upon for the completion before the work is finally completed, the sum so named being often a very extravagant one.

There are several ways of stating this clause, some of which are very much better than others. The following are the more usual forms:

I. *Provision for a specific "penalty."* When a specific "penalty" is named for either a particular or for any breach of the contract, whether this sum named be a per diem or a gross amount, the court will usually construe it as meaning that such

[1] The reader is requested to refer to Arts. 51–58 for a discussion of the legal phases of this question.

a sum is a fund provided in the specifications for the purpose of meeting such damages as may result from a breach of the contract, and that only the actual damages sustained and proved in a suit at law can be recovered from such fund. In other words, a penalty clause so stated has little or no force, since the law provides exactly the same remedy for any breach of contract, without a specific agreement.

II. *The naming of a per diem, or gross sum, as being the "ascertained and liquidated damages"* which will be sustained by the injured party for a specific breach of contract therein named, this usually being for failure to complete the work within the time specified. In this case the word "penalty" is not used, and if it can be made to appear on trial that both parties to the agreement really intended that the sum named should be forfeited in case of the failure therein described, and provided further this sum is not too extravagant and unreasonable, and provided the fact of failure and consequent liability be fully established, then and in that case the law will sustain the damage clause, and the injured party will be allowed to deduct it from any moneys due the contractor, or if this fund be insufficient, he may even sue the contractor and his bondsmen and recover the remainder. The following is a good example of this method of stating such a clause:

And the said party of the second part hereby further agrees that the said parties of the first part shall be and they are hereby authorized to deduct and retain out of the moneys which may be due or become due to the said party of the second part, under this agreement, as damages for the non-completion of the work aforesaid within the time hereinbefore stipulated for its completion, or within such further time as in accordance with the provisions of this agreement shall be fixed or allowed for such performance or completion, the sum of one hundred dollars per day for each and every day the time employed upon said work may exceed the time stipulated for its completion, or such stipulated time as the same may be increased, as hereinbefore provided, which said sum of one hundred dollars per day is hereby, in veiw of the difficulty of estimating such damages, agreed upon, fixed and determined by the parties hereto as the liquidated damages that the parties of the first part will suffer by reason of such default, and not by way of penalty.

A. P. B.

III. *An agreement that the engineer shall ascertain and make an estimate of the actual damages sustained* by a failure to complete the work within the time specified (or for other specific breach), and naming some or all of the items to be included in such estimate. In this case no effort is made in advance to determine what the actual damages are, and the agreement simply consists in making the engineer an arbitrator to act for both the parties in determining the amount of the damage as a question of fact. This is probably the strongest method of stating this clause, while it is also the fairest to all parties concerned.

Because of the difficulty in proving in a suit at law the actual damages sustained from the failure to complete an engineering contract within the time specified, the contractor usually pays very little attention to a penalty clause stated as described above in form I. As a rule, contractors are better informed as to the law of contracts than the engineers who write the specifications, and when this clause is stated as first described the contractor regards it lightly, well knowing that it has no particular significance. When stated in the second manner, however, provided the sum named be reasonable, the contractor will give it much greater weight, and the party paying for the work can withhold money under it with much greater assurance of being sustained by the courts. The courts, however, have a repugnance to any agreement made in advance as to questions of fact which in the nature of things could only be adequately determined after the breach had transpired. But because of the difficulty of fixing accurately the amount of such damages, even after the breach, the law consents to a previous agreement upon a specific sum, provided this be reasonable, and provided it be so clearly stated that the parties signing the contract can not have misconstrued it. Concerning the last method given of stating this clause, the law also has a repugnance to delegating the authority of the court to a layman in the person of an arbitrator. When, however, the question at issue is a "*condition precedent*" to settlement, as in this case of fixing the amount of the damages, and when this arbitrator is the engineer

in charge of the work, who is evidently the most competent person to estimate the amount of such damage, the law readily consents that he should act in such capacity, and if both parties have agreed that his decision should be final and conclusive in the premises, there would seem to be no way of evading his decision, except by proving that it was fraudulent. As fraud invalidates nearly all agreements, and nearly all obligations, if it can be shown that the engineer, when acting in the capacity defined in this clause, has knowingly and willfully overestimated the amount of the damage; in other words, if it can be shown that he acted dishonestly in the matter, his verdict can be set aside and the matter can come before the court. Otherwise the court will rule that his verdict must hold, and the question can not be opened. As it is very difficult to establish a question of motive, and as the burden of proof rests wholly upon the contractor, it would seem that this method of writing the damage clause had many advantages. The following is a fair example of such a clause:

In case said contractor shall fail to fully and entirely, and in conformity with the covenants, terms and agreements of this contract, perform, and complete said work, and each and every part and appurtenance thereof, within the time hereinbefore limited for such performance and completion, or within such further time as may be allowed by said board for such performance and completion, said chief engineer shall appraise the value of the direct and computable damages caused to said city by such failure, owing to the disbursements made by said city on account of the further employment of engineers, inspectors and other employees, including all disbursements for office rent, transportation, supplies and other matters connected with said employment; also the value of such other direct and computable damages as shall be caused by such failure; and the amount so appraised, when approved by said board, shall be deducted by said board out of such moneys as either may be due, or at any time thereafter become due, to said contractor under and by virtue of this contract, or any part thereof; and in case said appraised value shall exceed the amount of said moneys, then said contractor will pay the amount of such excess to said city, on notice from said board of the excess so due; and it is hereby agreed that the decision of said chief engineer as to the said

appraisal, when approved by said board,[1] shall be final and binding on both parties to this contract. E. K.

**87. The Discharge of Unpaid Claims of Workmen and Material Men.** The laws of many states provide that persons who supply either labor or material to any contractor or other person, to be used in the construction of any building or other permanent work, if not paid by such party, may file a lien upon such completed or uncompleted work, this serving as a kind of first mortgage upon the property, under which the property can be sold and the claim satisfied. When such a law obtains, the only safe course for the person paying for the work is to satisfy himself before he fully pays for the work that all such claims have been liquidated, or he may, if he choose, require the contractor to furnish a bond which may be sued upon, either by himself or by such material man or laboring man as may have such a claim. This bond to be large enough to cover all such liabilities.

When the party paying for the work desires to satisfy himself that such claims have all been discharged by the contractor, the clause may be written as follows:

Said contractor further agrees that he will pay punctually the workmen who shall be employed on the aforesaid work, and the persons who shall furnish material thereunder, and will furnish said board with satisfactory evidence that all persons who have done work or furnished materials under this contract and shall have filed any account of such claims with said board have been fully paid, or are not entitled to any lien under the laws of this state; and in case such evidence be not furnished as aforesaid, such amount as said board may consider necessary to meet the lawful claims of the persons aforesaid, shall be deducted from the moneys due said contractor under this contract, and shall not be allowed until the liabilities aforesaid shall have been fully discharged and the evidence thereof furnished said board; and if such evidence is not furnished before the final payment under this contract falls due, said board may pay such claims in whole or in part to the person or persons, firm or corporation claiming the same, and charge the amount thus paid to said contractor, who shall accept the same as payment to the amount thereof upon this contract. E. K.

[1] It may or may not be wise to make the verdict of the engineer subject to the approval of his principal

When the party paying for the work does not care to put himself to the trouble of obtaining the information as to the discharge of all such claims by the contractor, he may so frame the wording of the bond that it will cover this case satisfactorily. In this case this portion of the bond may read as follows:[1]

The said —— ——, as principal, and —— —— and —— ——, as securities, hereby bind themselves and their respective heirs, executors or administrators, unto the city of St. Louis, in the penal sum of —— dollars, lawful money of the United States, conditioned that in the event the said —— —— shall faithfully and properly perform the foregoing contract according to all the terms thereof, and shall, as soon as the work contemplated by said contract is completed, pay to the proper parties all amounts due for material and labor used and employed in the performance thereof, then this obligation to be void, otherwise of full force and effect, and the same may be sued on at the instance of a material man, laboring man or mechanic, for any breach of the condition hereof: provided, that no such suit shall be instituted after the expiration of ninety days from the completion of the above contract.

**88. No Claims for Damages on Account of Suspension of Work.** When the work contracted for is of a public character, as for a city or for the United States government, and when it is expected to continue for a considerable period, and be paid for by appropriations from time to time, and also in other like contingencies, it is common to insert a clause to the effect that the contractor shall make no claim for damages for necessary delays he may experience in carrying out the work, when these delays are caused by the failure of appropriations or by legal proceedings and the like.

On ten days notice the work under this contract may, without cost or claims against the party of the first part, be suspended by them for want of funds or for other substantial cause. Upon receipt by the contractor of the order for the suspension of the work, all the materials shall be piled up compactly, so as not to impede travel on the sidewalk or carriageway, or the use of fire plugs, gas or water-stops and all surplus material and rubbish shall be removed immediately from the

[1] This is the form universally adopted in all contracts made by the city of St. Louis. If not specifically so stated the material man or the laboring man could not sue on the bond.

street. When the party of the first part shall order the work to be resumed the contractor shall complete the same upon the terms and conditions of this contract. E. A. F.

**89. No Claims for Damages on Account of Delay.** In order that the party of the first part shall be freed from all claims which may be set up by the contractor for damages on account of various delays and hindrances which he may have experienced in carrying out the work, and which he may make appear to have been caused directly or indirectly by the party having the work done, or by other contractors upon the work, the following clause is often inserted:

The contractor shall not be entitled to any claims for damages for any hindrance or delay from any cause whatever in the progress of the work or any portion thereof, but said hindrance may entitle said contractor to such extension of time for completing the contract as may be determined by the engineer, provided he shall have given notice in writing of the cause of the detention. E. A. F.

**90. No Claims on Account of Unforeseen Difficulties.** In case it is the purpose of the contract to place upon the contractor all the responsibility for contingencies which may arise in the prosecution of the work, for which greater risk the party having the work done will, of course, pay in the increased price made by the contractor to cover such risk, the clause may be written as follows:

The contractor agrees that he will sustain all losses or damages arising from the action of the elements, the nature of the work to be done under the specifications, or from any unforeseen obstructions or encumbrances on the line of the work which may be encountered in the prosecution of the same.
E. A. F.

**91. Protection of Finished Work.** It is usually customary to hold the contractor responsible for the protection and care of the work until it is all finally completed and accepted. Even such portions of the work as have been completed and provisionally accepted and payments made upon the same should be taken care of and fully protected by the contractor until the entire work has been turned over. This often entails consider-

able expense upon the contractor, and when disputes on this question are liable to arise, it is well to insert such a clause as the following:

Contractors will be held responsible for any and all materials or work to the full amount of payments made thereon, and they will be required to make good, at their own cost, any injury or damage which said materials or work may sustain from any source or cause whatever, before final acceptance thereof. O. M. P.

92. **Protection of Property and Lives.** It is always understood that the contractor shall be held responsible for all damages to property which may arise from any fault of his, or from any accident which may occur during the performance of the work. He is also held responsible for all losses of life or limb, and for all personal damages which may be sustained either by his own workmen or by the public, by or on account of the works he has under construction. In other words, it is made his duty to protect both life and property, so far as possible, from all damage, so far as these may be traceable to the works themselves. If this responsibility were not specifically placed upon the contractor, the party having the work done would often be obliged to sustain the loss, since he authorizes the execution of the work, and the contractor is his employee or agent. This clause is often written as two separate clauses, one referring to the damage to property, and the other to the damage to persons.

Furthermore the wording of the bond is usually so made as to cover both of these items, so that in case the damage or loss is greater than could be repaid by the amount of money at any time due the contractor when the accident occurs, suit may be brought upon the bond against the bondsmen to recover the remainder.

Inasmuch as claims for damages, either to person or property, usually manifest themselves in the form of suits at law against the party authorizing the work and paying for the same, and not against the contractor himself, it is common to assume that this will be the case in all claims for damages, and

to word the clause accordingly. The following clause covers all of the above contingencies in an acceptable manner:

Said contractor further agrees that he will indemnify and save harmless said city and board, and the officers and agents thereof, from all claims, suits, actions, and proceedings of every name and description, which may be brought against said city or board, or the officers and agents thereof, for or on account of any injuries or damages to persons or property received or sustained by any person or persons, firm or corporation, by or from said contractor, or by or in consequence of any materials or explosives used on said work, or by or on account of any improper material or workmanship in its construction, or by or on account of any accident, or of any other act or omission of said contractor, or his agents, or servants, and said contractor also agrees that so much of the money due, or to become due, to him under this contract as shall be considered necessary by said board, may be retained by said board until all such suits or claims for damages, or otherwise, as aforesaid, shall have been finally settled and determined, and evidence to that effect furnished to the satisfaction of said board.

E. K.

The following is a common method of wording this clause, which defines the contractor's responsibility without referring to suits at law:

The contractor shall put up and maintain such barriers and red lights as will effectually prevent any accident in consequence of his work, for which the city might be liable, and he shall be liable for all damages occasioned in any way by his acts or neglect, or that of his agents, employees, or workmen.

E. A. F.

**93. Protection against Claims for the Use of Patents.** When it is anticipated that patented appliances or methods may be used either by the contractor in prosecuting the work, or as forming a part of the completed work itself, in order that the party authorizing the work may be able to collect from the contractor such fees as he may be forced to pay therefor, a special clause in the specifications may be written to cover this case. This clause may be as follows:

All fees for any patented invention, article or arrangements that may be used upon or in any manner connected with the construction, erection, maintenance of the work, or any part thereof embraced in these specifications, shall be included

in the price mentioned in the contract, and the contractor shall protect and hold harmless the party of the first part against any and all demands for such fees or claims, and before the final payment or settlement is made on account of the contract, the contractor must furnish acceptable proof of a proper and satisfactory release from all such claims. E. A. F.

94. **Assignment of the contract.**[1] If it is the intention of the party letting the work that the person or persons who take the contract shall perform the work themselves, without subletting it, it is necessary to prescribe that this shall be done in order to insure that it may not be sublet. One great objection to the subletting of contracts is that the subcontractor cannot be held directly by the principal, since these two have not entered into contract. The principal can only hold the original contractor, and all dealings with the subcontractor must be through him. This gives rise to delays and unsatisfactory performance, and is usually prohibited by the specifications. The following form is adequate to this purpose:

Said contractor further agrees that he will give personal attention constantly to the faithful prosecution of the work, and will not assign or sublet the work or any part thereof, or any of the moneys or orders payable under the contract, without the previous written consent of said board endorsed on this contract, but will keep the same under his personal control; that no right under this contract, nor to any moneys or orders due or to become due hereunder, shall be asserted against said city or board, or any department, officer, or officers thereof, by reason of any so-called assignment, in law or equity, of this contract, or any part thereof, or of any moneys or order payable thereunder, unless such assignment shall have been authorized by the written consent of said board endorsed on this contract; that no person other than said contractor now has any claim thereunder, and that no claim shall be made excepting under this specific clause of this contract, and under that clause relating to claim of workmen and materialmen. E. K.

95. **Contractor not Released by Subcontracts.** When it is anticipated that a portion at least of the work will be sublet to other contractors, and when in the nature of things this is advisable, it may be specified that such subletting of all or of any portion of the work in no wise releases the contractor from

[1] See Article 30.

ness to carry it out. That clause provided, therefore, that the engineer should under such contingencies be appointed to carry out the contract with the party of the second part, in his stead, the contract itself, however, still remaining in force, and the final settlement to be made in accordance with its terms.

For a similar set of contingencies as above described, the party of the first part may prefer to cancel the contract altogether, and instead of completing the work under the supervision of the engineer, he may prefer to let a new contract for the carrying on of the work. To do this, the contract itself must be rescinded or canceled, and in order to give the party of the first part the legal authority for doing this, a clause such as the following may be inserted. Here all moneys due upon the contract at the time the contract is canceled will be forfeited to the first party. See article 49.

In lieu of the exercise of the power hereinbefore given, in case of said contractor's default, to employ workmen, purchase tools and materials, and complete the work, said board reserves the right and option, instead thereof, to annul and cancel this contract and relet the work, or any part thereof, and said contractor shall not be entitled to any claim for damages on account of such annulment, nor shall such annulment affect the right of said city to recover damages which may arise from such failure on the part of said contractor to fulfill the terms of this contract. And in case of such annulment all moneys due said contractor, or retained under the terms of this contract, shall be forfeited to said city, and be paid to the credit of the fund for extending water pipe in said city; but such forfeiture shall, however, not release said contractor, or his sureties for the fulfillment of this contract, and said contractor and his sureties shall be credited with the amount of the moneys so forfeited toward any greater sum that they may become liable for to said city on account of the default of said contractor.

E. K.

**98. Workmen's Quarters and Other Temporary Buildings.** It is usually necessary for the contractor to erect temporary buildings for the protection of his tools and machinery, or for office purposes, and sometimes, when the work is at a distance from boarding house facilities, it is necessary for him to provide temporary quarters for his labor. The location, erection, and removal of such temporary structures should also be sub-

ject to the approval of the engineer in charge. If temporary quarters for workmen are not really necessary, it is best to prohibit them, at least to prohibit their erection on the property belonging to the party of the first part. The following is an example of such a clause:

The contractor may build such sheds, storehouses, etc., as are necessary for the work, but the location of such sheds, etc., must be such as will not interfere with the work of other contractors, and must be approved by the water commissioner. No buildings, sheds, or tents to be used as quarters for workmen or teams will be allowed on the city property.[1]

M. L. H.

**99. Cleaning up after Completion.** In nearly all kinds of engineering construction the grounds surrounding or along the line of the work are necessarily more or less defaced and encumbered by various disturbances of the surface, or by refuse and waste material, temporary buildings, etc., and it is usually made the business of the contractor on the completion of the work to clear up the grounds, and to put them in as presentable a condition as practicable. This does not involve any grading or removal of earth unless it be the excess or waste which remains on the natural surface from his own excavations. It does, however, include the cleaning up of his own work, whether it be buildings, foundations, masonry, conduits, pits, etc. The following is such a clause written to cover the case of waterworks engine pits:

When the work is completed, all pits, pipes, chambers, conduits, etc., shall be carefully cleaned out. The surrounding grounds shall be cleared of all rubbish caused by construction, all sheds, etc., and left in a neat and presentable condition.

M. L. H.

**100. Removal of Condemned Material.** Whenever any material which has been brought upon the ground by the contractor has been inspected and rejected by the engineer, or his assistants, it should at once be removed from the line of the work, in order to prevent its use when the engineer or his in-

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[1] To which might be added the following: Suitable privy conveniences shall be erected, as directed by the engineer, for the use of the workmen, and their use is made obligatory. The committing of nuisances is prohibited on all parts of the premises.

spectors are not present. To further insure against the use of condemned material by the contractor, it is sometimes specified that all such material shall be stored by the contractor in a specified place, where it shall be kept under lock and key, and under the control of the engineer only. In case the contractor declines to remove such material from the line of the work, or declines to take out any defective work, there should be a provision authorizing the engineer to do this at the contractor's expense. The following clause may be used:

Defective work and material may be condemned by the engineer at any time before the final acceptance of the work, and when such work has been condemned it shall be immediately taken down by the contractor, and rebuilt in accordance with the plans and specifications. When defective material has been condemned, it shall be at once removed from the line of the work, and stored as directed by the engineer, or otherwise disposed of to his satisfaction. In case the contractor shall neglect or refuse to remove or replace any rejected work or material after a written notice, within the time designated by the engineer, such work or material shall be removed or replaced by the engineer at the contractor's expense.

M. L. H.

**101. Relations to Other Contractors.** Where more than one contractor is expected to be engaged simultaneously upon the same work, it is well to insert a clause in the specifications defining the obligation of each of these contractors to the others in certain particulars as follows:

The contractor is required, so far as possible, to so arrange his work and to so dispose of his materials as will not interfere with the work or storage of materials of other contractors engaged upon the work. He is also required to join his work to that of others in a proper manner, and in accordance with the spirit of the plans and specifications, and to perform his work in the proper sequence in relation to that of other contractors, and as may be directed by the engineer.

M. L. H.

**102. Provision for Drainage.** Where the natural surface drainage is likely to be interfered with by the work of the contractor it may be specified that he shall maintain provision for such surface drainage during the progress of the work, and

that he will be held liable for all damages from his neglect to comply with this provision. The clause may read as follows:

If it is necessary in the prosecution of the work to interrupt or obstruct the natural drainage of the surface, or the flow of artificial drains, the contractor shall provide for the same during the progress of the work in such a way that no damage shall result to either public or private interests. For any neglect to so provide for either natural or artificial drainage which he may have interrupted, he shall be held liable for all damages which may result therefrom during the progress of the work.

**103. Provision for Public Traffic.** If it becomes necessary in the prosecution of the work to obstruct the public streets or sidewalks, and if it is practicable to carry on the work without closing these streets against all traffic it should be specified that

The contractor shall make suitable and adequate provision for the safe and free passage of persons and vehicles by, over, or under the work, while in progress. Such provision to be made to the satisfaction of the engineer. E. A. F.

**104. Contractor to Keep Foreman or Head Workman, and also Copy of Plans and Specifications on the Ground.** Whenever work is visited by the engineer or his assistants or inspectors, the plans and specifications should be available for examination and if instructions are to be given for the further prosecution of the work or for any changes or corrections, some responsible person should always be present who is authorized to receive such instructions for the contractor, as his agent. In this case the instructions given to this agent have all the legal force which they would have if given directly to the contractor. This clause may read as follows:

At all times when work is in progress, there shall be a foreman or head workman on the grounds, and also copies of the plans and specifications. Instructions given to such foreman or head workman shall be considered as having been given to the contractor. E. A. F.

**105. Cost of Examination of Completed Work.** Whenever the engineer desires to examine work which has been completed in whole or in part, this examination involving the tearing down of some portion of the work, and a corresponding

expense both in taking down and in reconstructing it, it is only fair to provide that in case the work should be found to have been performed in accordance with the contract, the cost of tearing down and rebuilding should be paid by the party of the first part; but if it should be found that the work had not been constructed according to the contract, this cost should fall upon the contractor. The following is such a clause:

Whenever required by the water commissioner, the contractor shall furnish all tools and labor necessary to make an examination of any work completed or in progress under this contract. If the work so examined is found to be defective in any respect, or not in accordance with this contract and specifications, the contractor shall bear all expenses of such examination and of satisfactory reconstruction.

If the work so examined is found to be in accordance with the specifications and contract, the expense of examination and reconstruction will be estimated to the contractor at a fair price to be determined by the water commissioner. M. L. H.

**106. Faults to be Corrected at any Time before Final Acceptance.** It should usually be understood between the parties that no act of the engineer or of the inspectors should be construed as final acceptance of any portion of the work, unless it is specifically so declared in writing by the engineer. Also that any failure to detect faulty or incomplete performance before the time of final acceptance should not be construed as an acceptance of the work. After the final acceptance by the engineer, the contract is no longer binding on the contractor in the way of requiring specific performance, but a reservation may be entered in the contract in accordance with which, if any defect or fault should subsequently appear which was undetected before the time of final acceptance, the party of the first part should have the right to recover damages for such fault or defect. A clause to this latter effect is not usually inserted, but it is legitimate if the circumstances should seem to require it. The circumstances might require it when the work is of such a character that faults could not readily be detected until the works had been put in operation. The following is an example of such a combined clause:

Failure or neglect on the part of the engineer or any of his authorized agents to condemn or reject bad or inferior work

or materials, shall not be construed to imply an acceptance of such work or materials if it becomes evident at any time prior to the final acceptance of the work and release of the contractor by the party of the first part; neither shall it be construed as barring the party of the first part, at any subsequent time, from the recovery of damages or of such a sum of money as may be needed to build anew all portions of the work in which fraud was practiced or improper material hidden, whenever found.

107. **Surveys, Measurements, and Estimates of Quantities not Guaranteed to be Correct.** It is not usually possible to give in advance complete measurements, dimensions, and estimates for all parts of the work. Especially is this true of the more detailed dimensions. It should always be understood, therefore, that the contractor must be responsible for the proper adjustment of the dimensions and details of the different parts of the work to each other and that the dimensions and figures given on the plans and specifications are always subject to changes during the progress of the work. The following clause refers especially to the construction of a steel viaduct:[1]

Contractors are also required to check all leading dimensions and clearances as a whole and in detail, the fitting of all details, and to become responsible for the exact position and elevation of all parts of the work, which will only primarily be located by the engineer of the department of public parks. They will maintain their own field engineering, that of the city being for the purposes of original lay-out, inspection, and checking. The contractor must provide and maintain such facilities for the engineer or his assistants as he may require for the convenient examination and inspection of the work in progress. He will pay the cost of testing all material in laboratories or shops, and the cost of such mill and shop inspection as he may be called upon to perform in addition to that furnished by the engineer, the selection of such laboratory or inspectors being dictated by the engineer, to whom they will report. He will furnish such monthly progress photographs as may be required to maintain the record. A. P. B.

[1] In this case both foundations and superstructure formed one contract. If the owner should prepare the foundations he must guarantee his surveys and locations to be as shown on the drawings, or as described in the specifications. In this case provision must also be made for a comparison of the standards of length used by the owner and by the contractor.

**108. The Contract Subject to Interpretation and Change by the Engineer in the Following Particulars:**[1]

(*a*) Where meaning is obscure and uncertain.

(*b*) As to what is implied beyond that which is specifically described.

(*c*) In case of discrepancies between plans and specifications.

(*d*) In case changes of plans or methods of work are afterwards decided upon.

Since the engineer is the author of the specifications, he evidently is the proper party to interpret their meaning. It goes without saying that the specifications and plans should be as clear and definite as possible in all particulars, but it is quite impossible to free language from many inherent defects, neither is it practicable to describe minutely and in detail all the parts of the work. There will, therefore, usually be some uncertainty as to the real meaning of the words used in the specifications, or even of the drawings themselves, and many of the details of the work must be understood by implication, rather than described in either the specifications or the plans.

Occasionally, also, by some oversight the plans and specifications will not agree. This usually results from changes of plan after one or the other has been drawn, such changes being made in the one place and not in the other. As a rule the specifications control, rather than the plans, and the figures on the plans control, rather than the actual dimensions of the drawings when taken to scale. The engineer should, however, be at liberty to determine what the real meaning was intended to be in all cases of discrepancies.

Very few contracts for large works are carried out from beginning to completion without changes being introduced in both the plans and in the specifications during the progress of the work. These changes may arise from a newly devised method or plan which may be considered superior, or from unlooked for obstacles met with in the work, or from suggestions on the part of the contractor himself. They also are frequently made in order to reduce the cost of the work, and

[1] See Articles 32, 33 34, 38 and 39.

on the other hand are sometimes made in order to improve its character. It should be understood, therefore, that the engineer has the privilege of making such changes in the plans and specifications at any time.

So far as the engineer may add to the plans or specifications by way of interpretation of their true meaning, as in (*a*) and (*b*), such supplementary and explanatory matter should not involve any change in the contract price.

In the matter of discrepancies, however, between plans and specifications, if the contractor can show that he based his estimate on one of these to the exclusion of the other, and when interpreted by the engineer, he finds he had estimated on a plan materially cheaper than that now required, it would be but just and right to allow him the difference in the cost, since he had the right to suppose that the plans and specifications were in accord.

When changes are introduced in the plans or specifications after the contract is let, such changes create a new contract, and as a matter of course there must be a new agreement as to compensation.[1] Without a special clause authorizing such changes neither party could change the terms of the contract against the will of the other without breaking it. Furthermore, without some understanding as to how the compensation should be determined for such change in plans or specifications, the party of the first part would be at the mercy of the contractor in this matter, and he could charge an extravagant price for such changes, and there would be no remedy. The following is a suitable clause, covering all these matters:

Said contractor also agrees that said chief engineer shall decide as to the meaning and intent of any portion of the foregoing specifications, or of the plans, where the same may be found obscure or in dispute; and said chief engineer shall have the right to correct any errors or omissions therein, when such corrections are necessary to the proper fulfillment of the intention of said plans and specifications; the action of such correction to date from the time said chief engineer gives due notice thereof. And it is also agreed by said contractor that said board may, at any time, make any changes in the location,

[1] See Section 38 as to the release of the sureties by such changes, and the provisions for changes in the bond itself, on page 508.

form, dimensions, grades, and alignments, and may make any variations in the quantity of the work to be done, as exhibited in the advertisement or notice of letting hereto attached, or in the form of proposal or bid for said work, and may entirely exclude any of the items of work relating to said quantities at any time, either before the commencement of the work, or during its progress, without thereby altering or invalidating any of the prices herein named, or this contract in any other respect; should such action diminish the amount of work that would otherwise be done, no claim shall be made for damages on the ground of loss of anticipated profits on work so dispensed with; and should such action be taken after the commencement of any particular piece of work, and result thereby in extra cost to said contractor, said chief engineer shall certify to said board the amount to be allowed therefor, which he shall consider fair and equitable, as between the parties, and his decision, when approved by said board,[1] shall be final and conclusive. E. K.

**109. Settlement of Disputes.**[2] While the contract lies between the party paying for the work, being the party of the first part, and the contractor who does the work, being the party of the second part, the contract itself is administered and enforced by the engineer, who is usually employed by the party of the first part. It is well understood also that the engineer is supposed to act always in a strictly professional and administrative capacity, that he has no personal interest in favor of, or against either party, and that his sole object is to see that the contract is faithfully carried out in accordance with its express terms and real meaning. It is also recognized that he is the most competent person to determine all differences and disputes, where these arise between the parties to the contract, or between two or more contractors engaged upon the same work. It is proper and right, therefore, that he should be made the referee in all cases of dispute or misunderstanding, and that his position as arbitrator should be made final and conclusive in the premises. If it be expressly agreed upon between the parties themselves that the engineer shall act in this capacity, then his decision does become binding and final

[1] This decision of the engineer is usually made final and conclusive without approval by his principal.

[2] See Articles 12 and 13.

upon the parties, even to the exclusion of the action of the courts, unless it can be shown that the engineer acted through prejudice, or ignorance, or fraud. As it is usually very difficult to establish a case against the engineer on either of these grounds, a clause such as the following usually acts to settle all disputes and to keep such controversies out of the courts. Honesty and fairness is also so common a characteristic of engineers that a clause such as the following is nearly always acceptable to both parties, and very seldom results in injustice being done to either party:

To prevent all disputes and litigation, it is further agreed by and between the parties to this contract, that said chief engineer shall be the referee, in all cases, to determine the amount, quality, acceptability, and fitness of the several kinds of work which are to be paid for under this contract, and to decide upon all questions which may arise as to the fulfillment of said contract on the part of said contractor, and his decision and determination, when approved by said board[1] shall be final and conclusive. Said contractor shall also afford all reasonable facilities for access to his work to any other parties or contractors who may be doing extra work or be working on a section of the conduit adjacent to his own, and any difference which may arise between two contractors in regard to their adjoining work is to be adjusted by said chief engineer, whose decision in the matter shall be final and binding upon both parties.[2]

E. K.

**110. Extra Work.**[3] While all changes in plans and specifications have been provided for in section 108, it is well to insert a special clause on the subject of extra work. It is common for contractors, on the completion of a piece of work,

[1] See foot-note, page 92

[2] In the opinion of the author of this work it is doubtful if a clause such as is here given will always stand in a court of law. The reader is referred on this subject to Articles 12 and 18 in the Synopsis of the Law of Contracts. In accordance with the principles there laid down it would seem that the courts will only sustain such a clause as the above when it can be shown that the acts of the engineer taken under it have been such as a court could properly refer to an expert referee, or to a person presumably more competent than the court to determine. In general such questions would be such as might be called "*Conditions Precedent*" to a legal settlement. Such "conditions precedent" would include all questions, such as the value of extra work, the amount of damages actually sustained from any breach of the contract, the extent of any failures to comply with the contract, and all matters which are not so much questions of fact as questions of quantitative and qualitative value, which can only be estimated, and which the engineer is presumably competent to evaluate. See also Article 86.

[3] See Articles 38 and 39.

to bring in a bill of extras, which they claim represents work which they were asked to perform, and which was not included in the plans or specifications, and which was not specially provided for by particular agreement with the engineer with the corresponding compensation to be paid for it. What the contractor's ideas or intentions may be on this subject does not usually develop until the work has been fully completed and the time of final settlement has arrived. In many instances it is then too late to determine the exact facts concerning this extra work, either because of the incompleteness of the records, or because of the impracticability of making the necessary measurements. Such a bill of extras, therefore, brought in at the time of settlement is always the source of a certain amount of difficulty and irritation, and when the piece of work extends over a considerable length of time, such a contingency as above described should be prevented by requiring all such bills of extras to be presented from month to month. Furthermore, it is desirable also that the contractor should reveal to the engineer his intentions in regard to claims for extras, before such extra work is executed. In this case if he will not accept of the price fixed by the engineer for doing such work the engineer should have the privilege of letting this extra work to another party. In this way extravagant prices for such work could be prevented, and disputes avoided, and the following is given as a good example of such a clause, on a piece of work which extended over a considerable period of time:

No claim for extra work shall be considered or allowed, unless such extra work shall have been previously ordered by said engineer, in writing. The claims for such extra work, when so ordered, shall be presented to such board on or before the 15th day of the month following that in which said extra work was done, otherwise such claims during that month will be forfeited and waived. In case any extra work shall be required in the proper performance of the work contemplated to be done under this contract, it is understood that said board reserves the right to have such extra work done by any other person, firm, or corporation than the said contractor, unless an agreement upon the prices to be paid for such extra work can promptly be reached between said board and contractor. Should said extra work be let to any other person, firm, or corporation than said contractor, said contractor further agrees

that he will not, in any way, interfere with, or molest such person, firm, or corporation, and that said contractor will suspend such part of the work herein specified, or will carry on the same in such a manner as he may be ordered by said engineer, so as to afford all reasonable facilities for doing such extra work; but said contractor agrees to make no claim for damages, or for any privileges or rights, other than expressed by this contract, by reason of the suspension and the doing of such extra work, except for an extension of time to perform this contract, as may be certified to said board in writing by said chief engineer, and approved by said board. E. K.

111. **Definition of "Engineer" and "Contractor."** While it is not at all necessary as a rule to define the terms "engineer," "contractor," "board," etc., it is usually well to insert such a definition, to prevent any legal quibble in case suit is brought by either of the parties to the contract. In this definition also the agency of persons acting for either of the principals or for the engineer is also defined.

Wherever the word "engineer" is used herein, it shall be and is mutually understood to refer to —— and to his properly authorized agents, limited by the particular duties entrusted to them.

Wherever the word "contractor" is used herein, it shall be and is mutually understood to refer to the party or parties contracting to perform the work to be done under this contract, or the legal representatives of such party or parties.

E. A. F.

112. **Documents Composing the Contract.** While in common law all the documents, acts, agreements, public advertisements, etc., which relate to or serve to explain the full meaning and intent of the contract, are made portions of such contract, it is well also to specify particularly what documents combine to make what is understood by the parties as "the contract." This clause is frequently inserted in the enacting agreement, which may or may not precede the specifications proper. It is here inserted as a clause in the specifications, but perhaps more properly belongs in what is sometimes designated more specifically as "the contract." The clause may read as follows:

It is understood by the contracting parties that the following documents are essential portions of the complete contract: The advertisement, the instructions to bidders, the proposal, all

drawings, maps, and plans, hereto attached or herein described, the specifications, specific contract, and the contractor's bond.

**113. Meaning Understood.** It is not unusual for contractors to enter a plea, either during construction or on final settlement, that such and such parts of the specifications were not understood, and that their bids were made under a misapprehension. To prevent the making of such claim the following may be inserted:

Said contractor hereby admits that he has read each and every clause in this contract, and fully understands the meaning of the same, and hereby agrees that he will comply with all the terms, covenants and agreements herein set forth. E. K.

**114. Provision for the Arbitration of Disputes.** The following provision for reference of disputes to arbitrators as a "condition precedent" to legal action is recommended:

In the event of disagreement between the company and the contractor, they shall submit the matter to arbitration, the company choosing one arbitrator, and the contractor one, and the two thus chosen to select a third.

The decision of such arbitrators, or a majority of them, shall be made in writing to both parties, and when so made shall be binding on the parties thereto.

The entire expense of such arbitration shall be borne by the party against whom the decision is rendered, or in event of a compromise decision, shall be borne by both parties in such proportion as the arbitrators may decide. Such arbitration is intended to avoid litigation and a written offer to submit thereto by either party, followed by such arbitration (if said offer is accepted and acted upon within twenty (20) days after the same is made) shall be a condition precedent to any action at law by either party under this contract. R. H.

**115. No Waiver of Legal Rights.** In large and complicated work it is well to insert a kind of blanket clause against a misconstruction of any act of the engineer, or of his assistants, or of the owner, by making such act a bar against the final enforcement of the contract in all its parts, not actually prohibited by such antecedent acts. The following is a good form for such a clause:

Neither the inspection of the company, engineer, or any of its employees, nor any order, measurement or certificate by the engineer, nor any order by the company for the payment of

money, nor any payment for, nor acceptance of, the whole or any part of the work of the engineer or company, nor any extension of time, nor any possession taken by the company or its employees, shall operate as a waiver of any provision of this contract, or of any power herein reserved to the company, or any right to damages herein provided; nor shall any waiver of any breach of this contract be held to be a waiver of any other or subsequent breach. All remedies provided in this contract shall be taken and construed as cumulative:—that is, in addition to each and every other remedy herein provided; and the company shall have any and all equitable and legal remedies which it would in any case have. R. H.

**116. The Use of General Clauses in Engineering Specifications.** While the general clauses here described with illustrative examples may appear to the reader unnecessarily voluminous, their purpose and effect is to clearly define the business relations of the parties, and to prevent injustice being done to either party. They are also calculated to prevent litigation and delay in the final settlement, and if they are able to effect these ends they are well worth inserting, even where the work to be done is relatively small, and unimportant. The engineer should be careful, however, that all such clauses are consistent as between themselves, and it is best also to make them mutually exclusive. In other words, the same thing should not be described or defined in more than one clause, as repetitions only weaken the document. Furthermore, *no condition or limitation should be inserted without a full intention of strict compliance.* If the engineer begins to relax in his requirements in one particular, the contractor will not be slow to take advantage of such precedents, and to claim similar privileges in other directions. If the engineer could know in advance who the contractor was to be, many of the clauses here offered might be dispensed with, in case the contractor was known to be thoroughly honest and competent. The specifications are prepared in advance, however, and it is wise to assume that the contractor will be a more or less irresponsible party, without reputation to sustain, and whose sole object is personal gain. It must also be understood that the clauses here given are offered only as illustrative examples, and not to be blindly copied. The engineer in writing the specifications

should have clearly in mind what the business relations are intended to be, and make his general clauses consistent with that conception. He could probably consult other specifications, or the clauses as given above, as suggestions and to enable him to avoid omitting some essential condition which he wishes to insert. It is believed by the author that the clauses here quoted have the support of the leading members of the profession in this country, and that they are well adapted to determine the conditions which the engineers who use them desired to impose. It must not be supposed, however, that all these general clauses would ever be embodied in any one specification.

# PART III.

## Specific Descriptive or Technical Clauses in Specifications.

**117. Essential Features of Good Specifications.** We now come to consider that portion of any given set of specifications which relates to and describes the work itself. In writing specifications of this kind, the following requirements should be complied with:

(*a*) The work should be described first as a whole, and then in detail.

(*b*) Every portion and detail of the work should be described in clear and simple language which will be understood by the contractors who are supposed to bid on the work. These descriptions should have reference to the ultimate end to be accomplished rather than to the means and methods to be employed. It is usually not wise to specify methods unless in the opinion of the engineer some particular method is far preferable to any other.

(*c*) The clauses in the specifications should be made so far as possible mutually exclusive. That is to say, no part of the work should be specifically described in more than one place. Repetition of descriptions tends to weaken the document.

(*d*) The specifications should be clear in the matter of indicating what is absolutely required without any alternative, and what is named as indicating in general the character of the product, and in which alternative materials, methods, or results will be allowed. If the engineer anticipates that some clauses in the specifications are to be rigidly insisted upon, while others will not be specifically enforced, this intention or state of mind of the engineer should be revealed in the specifications themselves. In other words, the contractor should know in advance

how the specifications are to be interpreted, so far as it is possible to give this information in the specifications.

(*e*) The last named requirement demands that the engineer should be so familiar with all the details of the work described, from actual experience, that he is able to know in advance what his decision will be in the various contingencies which may arise during the progress of the work. His foresight in this particular must be complete and distinct, which can only be the case when the engineer who writes the specifications has had considerable experience in carrying out practically the same kind of work.

(*f*) In choosing units of measure, in describing the work, to be used for determining compensation, only specific and definite units should be chosen, or they should be so defined as to admit of no double meaning. For instance, to say that mortar shall be composed of one part cement to two parts of sand comes very far from defining a particular ratio of ingredients. If the words "by weight" be added, it still fails to define, inasmuch as wet sand is much heavier than dry; or if the words "by measure" be used, this also fails to define, since cement may be measured in the original package, where it is thoroughly compacted, or it may be dumped and measured in a fluffy condition, in which it occupies some 50 per cent. more volume.

(*g*) The engineer should be familiar with the ordinary methods employed by different kinds of mechanics and should so design his work as to obtain satisfactory results without requiring a much higher grade of work than is customary by the mechanics who will be called upon to execute it. It is practically impossible with the most thorough supervision and inspection to get mechanics to vary their ordinary practice materially. The failure to recognize this fact often leads engineers to specify methods or results which are practically unattainable, and this leads either to continual violation of the specifications and its accompanying irritations and delays, or to an abandonment on the part of the engineer of the strict interpretation of his own specifications.

(*h*) In the matter of materials it is customary to specify

not the very highest and best the market affords, but such a grade of material as would be satisfactory in service, and which can be supplied by the standard manufacturers of that particular product. In this way the engineer gets the benefit of a wide competition, and of a correspondingly low price. The minimum requirements for materials which serve as a criterion of rejection determines very largely the cost of the work. If, therefore, the engineer in preparing his design bases his calculations upon what might be commonly known as good or first-class materials, with a minimum limit fairly below this generally recognized first-class grade, he will usually obtain a material practically as good as the market affords, without being obliged to pay an extravagant price for it, and without suffering from the delays and troubles caused by the rejection of a large proportion of the material furnished. To base a contract on the very highest tests known of a given material, and to require this extraordinary quality for all the material furnished is extremely unwise.

(*i*) If possible to avoid it, it is best not to specify a particular manufactured product or proprietary article by name. If this is done at all, more than one such name should be given if possible, and others admitted if shown to be as good as these to the satisfaction of the engineer. To limit the materials or articles specified to that of a single manufacturer subjects the engineer to invidious criticism and suspicion, and it is always wise to avoid even the appearance of evil.

(*j*) It is not uncommon to specify that the materials furnished shall be of well known brands, or the products of factories or works of established reputation. Similarly it is sometimes specified that the contractor himself must show a familiarity with the work he proposes to perform. Also in the matter of stone, for instance, that it shall be taken from quarries which have been in long use, the stone from which by actual use is known to have good weathering qualities.

(*k*) Before writing the specification, the engineer must also have a clearly defined notion as to the amount of responsibility which is to be placed upon the contractor. If the engineer prescribes the plan, the materials, and the methods to be em-

ployed, he, of course, assumes all responsibility so far as these are concerned, and he can not in justice make the contractor responsible for his own faults.[1] He should always be ready and willing to take upon himself such responsibilities pertaining to the design as properly belong to the designer. For instance, if the contractor is held responsible for the results, he must be given a considerable latitude as to methods, and if the engineer prescribes the plan, the materials, and all the methods to be employed, he cannot hold the contractor for the results, or for the successful operation of the project, beyond the simple faithful performance of the work prescribed. In general the entire responsibility for the successful operation of the work should rest upon the engineer. It is only in case of extra-hazardous undertakings, which are largely of the nature of an experiment, in which no well defined plan is outlined, that the contractor is left comparatively free, both as to plan and execution. It is only in such cases that the engineer is warranted in relieving himself of all responsibility, and placing the same wholly upon the contractor. There are cases in which contractors have, by experience, acquired peculiar ability to perform certain kinds of hazardous work, and who are willing to undertake the same under a guarantee of successful execution, under which circumstances, any engineer, even of high repute in his profession, would be warranted in letting a contract and putting the entire responsibility upon the contractor.

(*l*) A strong reason for enforcing specifications literally and rigidly, instead of accepting some other materials or method which possibly may be "just as good" is to be found in the relation the engineer and owner hold to other contractors who bid upon the work. It is to be presumed that these other parties have based their estimates on a strict compliance with the specifications, and it is possible that the lowest bidder has presumed on his being able to substitute cheaper materials or methods for those specified. If he is allowed to do this after the contract is let, it is evident that the other bidders have been discriminated against to their disadvantage and under a species

[1] See editorial in the Engineering Record, February 17, 1900.

of fraud, which should not receive the encouragement of either the engineer or of the owner. It is difficult, therefore, to see how a cheaper grade of work can properly be accepted in lieu of that specified, even though it be "just as good," without encouraging this practice of presuming upon a cheaper fulfillment, and also without treating the other bidders unfairly. Other things being equal, therefore, it is best to rigidly enforce a contract, even though a cheaper material or method might, in the opinion of the engineer, be employed with equally good results. Or, if a cheaper compliance is allowed, a corresponding reduction in price should be insisted upon.

The above are some of the numerous controlling ideas which the engineer should have clearly in mind in the writing of a set of engineering specifications. He must know in the first place exactly what he wants, and then try to so describe it that others cannot mistake his meaning. The general and detail plans are usually made before the specifications are written, and the engineer has these before him in writing the specifications, and makes liberal reference to them. Since they are also a part of the specifications, he has the advantage of a double language in which to present his ideas, and, if he does not succeed in making clear to the proposed contractors exactly what is to be done, he should feel that he alone is to blame for any misunderstanding.

**118. Specifications Accompanying Complete Detail Plans.** As described in article 17, we have in general three classes of engineering specifications, describing the work itself, namely:

Specifications accompanying complete detail plans.

Specifications accompanying a general plan only.

Specifications unaccompanied by any plan, and commonly known as general specifications.

When the specifications are accompanied by complete detail plans, these plans are prepared before the specifications are drawn, and in this case the specific descriptive specifications are largely composed of descriptions of the materials to be used, the methods of manufacture and erection, and of the results to be accomplished, or of the tests to which the finished product is to be subjected. Such complete detail plans are al-

ways necessary when a particular and definite plan is to be carried out. When the work is to be let in open competition, and to the lowest bidder it is also usually best to prepare complete detail plans in order to insure that the bidders will all estimate on exactly the same thing, and further, to insure that the final product will be satisfactory. In this case the detail plans must be duplicated by some of the various methods of copying drawings, and in very large and important work frequently by photo-lithographing, and these copies of the plans submitted along with the specifications to the various parties wishing to bid upon the work. If the bidders are expected to be those residing in the immediate vicinity, it is not so necessary to duplicate these drawings, all the bidders being asked to examine the drawings in the office of the engineer. In this case the drawings usually are self-explanatory even to the extent of indicating the materials to be used, so that the written specifications need not describe the work as to its form and dimensions, but are only descriptive of the work in a general way.

**119. Specifications Accompanying a General Plan Only.** In this case the bidder is asked to submit detail plans for the work in submitting his bid, the specifications being so framed, however, as to reduce all designs which fully comply with these requirements to a common standard of value. To accomplish this purpose the engineer must be able to foresee practically all the various designs which may be submitted, and to anticipate all the advantages in economy which are likely to control the preparation of these designs, and to make such requirements in the specifications as, when complied with, will in his opinion give products of equal efficiency, capacity, and permanency. In this way the engineer gets the advantage of the experience and of the inventive genius of all the persons bidding upon the work, with the chance that he may secure a better design than he himself would have been able to prepare, and also one which may cost materially less than his own design. As an illustration of this kind of specification, we may have a bridge or roof truss of a particular general design, the outline drawing showing simply the general dimensions, and the location of the

members, this fixing the general style of truss, which for some particular reason the engineer wishes complied with. The contractor is then asked to build a truss on these general lines in compliance with the accompanying written specifications.

**120. Specifications Unaccompanied by Plans, Known Commonly as General Specifications.** In this case no plans whatever are prepared, but only the most general requirements to be satisfied. As, for instance, in the case of a bridge, the total span, the loads to be carried, the character of the stream to be bridged (this determining the character of false works required, and often determining the character of the superstructure itself), the kinds of materials to be used in its construction, the maximum unit stress allowed in the various parts, etc. Or if the contract is for machinery, the specifications may define the amount and kind of work to be done, which fixes the capacity of the apparatus. They would also define the efficiency or economy of operation of the plant, and make various requirements in regard to the material used, and methods of construction which would be supposed to govern its permanency. In this case, as in the one preceding, the engineer must have constantly in mind in writing the specifications the possibility of complying with them with some kind of cheap product which, while fulfilling the letter of the requirements of the specifications, would not be at all what he hopes to obtain, or what would be consistent with the more standard forms of construction.

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## ILLUSTRATIVE SPECIFICATIONS OF VARIOUS ELEMENTARY PORTIONS OF ENGINEERING WORK.

**121. Scope and Purpose.** It is proposed in the following articles to give illustrative examples of what is considered good practice in describing many of the more common elements of engineering construction. The practice pursued in discussing the general clauses in engineering specifications, of first con-

sidering the purpose of the clause, and then giving an illustrative example, will be followed here. Frequently, however, more than one illustration will be given, and the sources from which they are obtained will also be indicated. It is thought this arrangement will serve a better purpose than to give a series of complete specifications of various kinds of engineering work, without a detailed discussion of the several clauses. By the arrangement here used duplication of parts is avoided, and the reasons for the particular descriptions can be given in their proper connection. These reasons will perhaps be more useful to the young practitioner than the particular specifications themselves.

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## SPECIFICATIONS ON EXCAVATIONS AND EMBANKMENTS.

122. **Earth Work, Excavation, and Grading.** A specification for excavation, or grading, should satisfactorily cover the following ground:

(*a*) Location and general description of the work.

(*b*) As full a description of the character of the materials to be excavated as can be furnished.

(*c*) A classification of the materials which will be employed, and the methods of measurement.

(*d*) A description of the lines of limits of excavation and fill, including borrow pits, and waste banks.

(*e*) The disposition to be made of the excavated materials.

(*f*) The distance to which the material is to be transported, commonly included under the general head of "Haul."

It is always wise for the engineer to determine in advance approximately the character of the material to be encountered and to give to the contractor the benefit of such information. It is not wise, however, for him to guarantee the quality of the material to be as indicated, since this furnishes to the contractor grounds for claims which the engineer will find it difficult to adjust. The character of the material is usually learned

approximately by borings along the line of the work. In the case of railroad work it is not customary to do this, but from the general knowledge of the geologic formations, the various kinds of materials can be fairly anticipated.

The specifications should be very explicit and clear beyond all possibility of doubt in the matter of grades or classification of materials to be encountered, and the methods which will be used in measuring the quantities. Innumerable difficulties are constantly arising in the carrying out of engineering specifications from misunderstanding on these points. Materials encountered in excavation are not only various as to quality, but all gradations are found, so that it is practically impossible to determine where one classification or kind of material ends and another begins. In fact two engineers will often classify the same materials differently under the same specifications, and there is no possibility of determining such questions, except by agreeing to abide by the decision of the engineer. It is best not to have too many classes of materials, and all kinds of materials are usually grouped under three general heads, namely: *Earth, loose rock,* and *solid rock.*[1]

**123. Grading.** The following specifications for railroad grading are used by the Pennsylvania railroad:

Under this head will be included all excavations and embankments required for the formation of the roadbed; cutting all ditches or drains about or contiguous to the road; the foundations of culverts and bridges, or walls; the excavations and embankments necessary for reconstructing turnpike or common roads, in cases where they are destroyed or interfered with in the formation of the railroad; and all other excavations or embankments connected with or incident to the construction of said railroad.

All cuttings shall be measured in the excavations, and estimated by the cubic yard, under the following heads, viz: *Earth, Loose Rock, Solid Rock.*

*Earth*—Will include clay, sand, loam, gravel and all other earthy matter, or earth containing loose stone or boulders intermixed, which do not exceed in size three cubic feet.

[1] In the specifications used on the Chicago Drainage Canal but two classes of materials were named "Solid rock" and "Glacial drift." Where no solid rock was anticipated, but one class was named, and this was called "Excavation." Sometimes more than three classes are recognized and provided for when the grades are distinct and well marked.

*Loose Rock*—Shall include all stone and detached rock lying in separate and contiguous masses containing not over three cubic yards; also, all slate or other rock that can be quarried without blasting, although blasting may be occasionally resorted to.

*Solid Rock*—Includes all rock occurring in masses exceeding three cubic yards, which cannot be removed without blasting.

The roadbed will be graded twenty feet wide in earth cuttings and fifteen feet in fillings, except where otherwise directed by the engineer, with side slopes of such inclination as the engineer shall in each case designate, and in conformity to such depth of cuttings and fillings as may have been or may hereafter be determined upon by said engineer.

Earth, gravel and other materials taken from excavations (except when otherwise directed by the engineer), shall be deposited in embankments, the cost of removing which will be included in the price paid for excavation. All material necessarily procured from without the road and deposited in the embankments will be paid for as excavation only. In procuring materials for embankment from without the line of the road, the place will be designated by the engineer in charge of the work; and in excavating and removing it, care *must* be taken to injure or *disfigure* the land as little as possible. The embankments will be formed in layers of such depth (generally one foot), and the materials disposed and distributed in such manner as the engineer may direct, the required allowance for settling being added.

No borrow pits will be opened nearer than four feet from base of embankment slope, and will receive same slope as corresponding embankment. All borrow pits will be excavated in a regular manner and so as to leave no holes for standing water, generally with a descent at bottom to allow free passage of water.

Wherever the excavations furnish more material than is required for embankments, the surplus will be used to increase width of embankment, or deposited in spoil banks or waste piles, as and where the chief engineer may direct.

The roadbed, in cuts and on banks, to be made in a workmanlike manner; to be perfectly even and regular according to grade stakes as set from time to time by the engineer in charge, and to be exactly of the width directed.

All slopes to be formed even and straight, according to slope stakes, and to such incline as directed in each case.

All ditches in cuts or along banks to be made of such width and grade as the engineer in charge may direct.

If the contractor shall make excavations or embankments in

excess of the directed width, then such excess shall not be paid for.

Over culverts and behind bridge abutments the embankments shall be formed carefully, so as to avoid damage to, or bulging of, the masonry. Only the best materials will be used for this purpose, the same to be deposited in layers of not over ten inches thick. The contractor to be responsible for any damage to the masonry.

Contractors, when directed by the engineer in charge of the work, will deposit on the side of the road, or at such convenient point as may be designated, any stone or rock that they may excavate; and if, in so doing, they should deposit material required for bank, the additional cost, if any, of procuring other materials from without the road will be allowed. All stone or rock excavated and deposited as above will be considered the property of the railroad company, and the contractors upon the respective sections will be responsible for its safe keeping until removed by said company, or until the work is finished.

The line of road, or the gradients, may be changed if the engineer shall consider such change necessary or expedient; and for any considerable alterations, the injury or advantage to the contractor will be estimated, and such allowance or deduction made in the prices as the engineer may deem just and equitable; but no claim for an increase in prices of excavation or embankment on the part of the contractor will be allowed or considered, unless made in writing before the work in that part of the section where the alteration has been made shall have been commenced. The engineer may also, on the conditions last recited, increase or diminish the length of any section for the purpose of equalizing or balancing the excavations and embankments.

Whenever the route of the railroad is traversed by public or private roads, commodious passing places must be kept open and in safe condition for use; and in passing through farms the contractor must also keep up such temporary fences as will be necessary for the preservation of the crops.

The above specification makes no provision for what is commonly called "haul." By "haul" is meant an additional compensation for carrying the excavated material beyond a certain limiting distance. Such a provision usually accompanies a specification for excavation, and may be given in the following language:

The price paid for "excavation" in all the several classes thereof will be understood to cover and pay for the entire

expense of its removal by any method whatever, including loading, unloading, transportation and deposit in the manner prescribed in these specifications, in the places designated by the engineer, provided the haul of the material so transported does not exceed —— ( ) feet, and beyond that distance —— per cubic yard per one hundred (100) feet will be allowed and paid, for such extra haul, in addition to the price paid for excavation.

124. **Excavations Under Water.** Excavations made under water are usually for the purpose of securing a channel for the passage of boats. In many cases the character of the material is quite various, and largely unknown. It is proper for the engineer to make such investigations as are practicable to discover what these materials are, and to about what depth the cutting will have to be made, and to give the contractor the benefit of such information. It would not be well for him, however, to make positive statements as to the character of the material, and he should relieve himself in the specifications of all responsibility for the information given. The contractor on the other hand should inform himself of the nature of the work so far as possible, both by personal examination, and by availing himself of the investigations of the engineering department. The following paragraphs concerning excavations under water are taken from the standard specifications used by Col. O. M. Poe, of the corps of engineers, U. S. army.

All available information in the possession of the United States will be given upon application. The United States will not guarantee the correctness of its information and will not be responsible for the safety of the employees, plant or materials used by the contractor, nor for any damage done by or to them from any source or any cause. Bidders are expected to satisfy themselves as to the nature of the work to be done, and it will be assumed that proposals are based upon a thorough understanding of its character. Intending bidders are urged to visit the localities of the work, and, by personal inspection and inquiry, fully inform themselves as to the present and probable future conditions. Navigation shall not be obstructed, and no allowance or concession will be made for any lack of information on the part of the contractor regarding the work. The price bid shall be full compensation for furnishing all necessary labor, materials, and appliances of every description, and for doing all work herein specified to the satisfaction of the engineer officer in charge, and shall include all

risks and delays of whatever nature attending the execution of the work.

The work comprises the improvement of two shoals in St. Mary's River, Michigan, above the canal. The upper shoal lies northwesterly, and the lower shoal northeasterly from old Round Island Light House.

The work to be done consists in excavating a channel within the side and end lines prescribed by the United States agent in charge, said channel to have a bottom width of 300 feet, and a total length of about 3,000 feet, the estimated excavation being 90,000 cubic yards, bank measure, more or less. The greatest distance to the dumping ground will not exceed two miles, and the average distance will not exceed one mile.

The material to be removed consists of boulders, clay, sand, gravel, and possibly hard pan, all in unknown proportions.[1]

The bottom of the completed cut shall be in a plane 25.32 feet below the upper surface of the coping of the lock of 1881 in St. Mary's Falls Canal, the face of excavation probably varying from scraping to 5 feet.

No payment will be made for excavation below 22 feet depth of water. All excavations within the specified side slopes and between 21 and 22 feet depth of water will be paid for at half rates in the final estimates.

Proposals will be received for bank measure only. For the monthly estimates 30 per cent. will be deducted from scow measurements, but the total of the estimates made for the upper shoal will never exceed the total of the estimates made for the lower shoal, until all the required excavation has been finished at one of the shoals, and an equal amount of excavation has been done at the other.[2] O. M. P.

[1] In letting this work all materials were entered in one class, even though it were solid rock In this particular instance no solid rock was anticipated, and hence it is not mentioned in the list of materials to be encountered, but in other sections solid rock was anticipated, and was so entered in the list of materials, but the proportion in each class was left for the contractor to estimate as best he could from the investigations made by the engineering department, and such additional borings as he might make himself, there still being but one price per cubic yard for all materials. The responsibility of the contractor in this connection is fully defined, however, in the extract given above.

[2] This work was let by the cubic yard as measured in bank. That is, from soundings taken both before and after the excavation between the side lines indicated and above the depth of 21 feet. Material excavated below the depth of 21 feet and above the depth of 22 feet was paid for at half rates. Any excavation below the depth of 22 feet was not paid for at all. Neither were the excavations made outside the side boundaries. In other words, the material was paid for in cut as it would be described in earthwork out of water. The reason for requiring the work on one shoal to be fully completed before an equivalent sum is paid for the other is to insure the completion of the work. If a small amount of material had been left above the 21-foot line in various places, the excavation of these scattered portions would be very expensive per cubic yard, and if the contractor had already received the major part of his compensation it might be difficult to induce him to finish up the work properly.

**125. Specifications for Measuring Quantities Excavated Under Water by Weight and Displacement.** The following specification is taken from the United States Engineer Corps specifications for excavation in the James River, and they illustrate another method of determining amount of material excavated. In this case the soundings in the river are only used for determining when the excavation has been completed to the proper depth, and to prevent excavation beyond a limit of over-depth:

CLASSIFICATION.—Mud, sand, clay, and gravel, under the class *"earth excavation,"* will include those materials, however hard or compact they may be, the gravel to include pebbles up to three inches in diameter. *"Cobble"* will include stones up to three cubic feet. *"Soft rock"* will include any rock in place which can be removed by dredges without blasting, although, for economy in removal, blasting is resorted to, and will include the disintegrated rock found for two or three miles below Richmond. *"Solid rock"* will include rock which rings under the hammer, boulders measuring over three cubic feet, and other rock which, in the opinion of the engineer officer in charge, cannot be removed without blasting. When soft and solid rock occur together, in strata or otherwise, the amount of each will be ascertained by the inspector after the material is placed on lighters. Mixed classes of material must be separated by the contractor, at his expense, for measurement by displacement as the lighters are unloaded at the place of deposit.

UNCLASSIFIED ROCK.—In place of bidding on soft and solid rock separately, an alternate bid may be submitted for *unclassified rock,* which will include all material described in these specifications as rock, *whether soft or solid.* The bid will be for the ton of 2,000 pounds, and the weight will be ascertained by displacement, as hereinafter described. The bidder on this class will specify a price for extra haul *per ton of 2,000 pounds.*

Should the bid for unclassified rock be accepted on any section, the price per ton will be stated in the contract in lieu of those for soft and solid rock. On such section the contractor must begin the excavation of areas known to be of solid rock in part, with other areas, as directed by the engineer, and continue their excavation, or accept an equivalent reservation in tons, according to the relative cost of excavating soft and solid rock, to be determined by the engineer, until such solid rock excavation is made.

MEASUREMENT OF EXCAVATION.—All materials excavated in the two and a half miles below Richmond and at Drewry Bluff will be measured on deck lighters by displacement of water taken at 62 pounds per cubic foot. The basis of measurement for "solid rock" will be 155 pounds and of soft rock 120 pounds, and of other classes 120 pounds per cubic foot, until otherwise ascertained at the instance of either the engineer or the contractor. These "other classes" will then be loaded on deck lighters (with gauges attached) whose cubic feet of submergence has been ascertained for each tenth of a foot. The load will be put on in shape suitable for accurate measurement by cross sections, at the expense of the contractor, and in such manner that the plane of submergence will be parallel to the deck of the lighter, as near as may be. The difference in cubic feet of submerged section, light and loaded, at 62 pounds to the cubic foot, will be considered the weight of the measured load. The lighters must be kept bailed out, and will be considered loaded with the same weight when afterward sunk to the same gauge readings. The proportion of a partial to a full load will be determined by the ratio of the displaced volumes of water.

The engineer may measure the displacement of empty lighters at his discretion, and the contractor must free them from water at his own expense whenever requested by the inspector for the purpose of determining their loads.

DUMPING LIGHTERS will not be allowed in transporting materials excavated at Drewry Bluff or above, but can be used for material excavated at Harrison's Bar and Goose Hill Flats.

Where dumping lighters are used, measurements will be made by the capacity of the pockets.

DECISION AS TO QUANTITIES.—The duty of determining the quantity of material carried in or on lighters will be performed by inspectors appointed by the engineer in charge, and the decision of such inspectors, acting under the orders of the engineer, as to the amount of material excavated and removed, as well as to its place and manner of deposit, shall be final and without appeal on the part of the contractor.

OVER-DEPTH.—No allowance will be made for dredging more than twelve inches below the required depth or outside the limits of the channel as marked by stakes or ranges, unless such additional depth is necessary to break up strata of rock or cemented earth. Increased depth will be allowed in such cases if authorized by the inspector, acting under the direction of the engineer. If a deficiency in depth is found the contractor must re-excavate the bottom until the required depth is obtained.

Dumping.—Excavated material will be the property of the United States and be disposed of strictly in accordance with instructions from the inspector. W. P. C.

**126. Specifications for an Earthen Dam.** The following specification for an earthen dam across a stream for a storage reservoir for irrigation purposes is a fair illustration of a method of writing the specifications for such a purpose. It is sufficiently elastic to allow the engineer great discretion in the matter of adapting the methods to the particular material encountered, while at the same time it gives to the contractor a fair idea as to the amount of work which will be required of him, and therefore as to its approximate cost. This is really all he cares to know at the time he makes his bid.

The object in the mind of the engineer in writing this specification was to make as impervious a dam as possible with the materials which were known to exist in the immediate vicinity, without making the cost extravagant. The earthwork was well insured against overflow by having a very long spillway across the dividing ridge between this and an adjacent drainage basin some distance above the dam.

Specification for an Earthen Dam.—After the work has been staked out, the top soil and all vegetable matter shall be wholly removed from the area of the work. This area shall be cleared to the satisfaction of the engineer, and no allowance will be made therefor. The material removed, which is sufficiently free from vegetable matter, may afterwards be used for building the outer toe of the dam.

The sides of the valley shall be terraced or stepped with risers one foot high, over the whole area of contact with the dam. These terraces shall also have offsets horizontally as shown in the sketch. They shall be cut to the depth indicated by the engineer, and the material excavated will be paid for as excavation.

A trench shall be opened from the surface to and into the gravel stratum, of the dimensions as shown on the drawings, being about 16 feet wide at the surface, and about 6 feet wide at the bottom. This trench extends the entire length of the dam and up to the side slopes; it extends to the rock after the gravel stratum is passed. This work will be paid for as excavation.

A puddle core wall extends the whole length of the dam, being 6 feet wide at the bottom of the trench, which averages

about 20 feet below the surface of the ground, averages about 16 feet wide at the surface of the ground, and is 6 feet wide at a point 4 feet below the top of the dam.

This puddle core is to be a mixture of clay and the gravelly sand such as found in the gravel stratum (all of the gravel to be such as will pass through a 2 inch ring), in about equal proportions. These two kinds of materials will be spread in alternate courses about 3 inches thick. The clay courses will be harrowed sufficiently to pulverize the hard clods, using a disc harrow, or such other machine as may be satisfactory to the engineer. A gravel course will then be laid and this harrowed until it is thoroughly incorporated and mixed with the clay. It shall then be wet down and allowed to stand until it is in a proper condition for compacting, when it shall be rolled thoroughly, to the satisfaction of the engineer, with a grooved roller weighing not less than 150 pounds to the lineal inch along the axis of the roller.

On this shall then be laid another 3 inch layer of clay, which shall be pulverized by harrowing, to be followed by a 3 inch layer of gravel, harrowed, wet down and rolled, as before described, and so on. If, in the opinion of the engineer, it is deemed advisable, or desirable, the clay for the puddle shall be pulverized dry before it is spread on the dam.

The above describes, in a general way, the amount of work which will be required to be done on the puddle core of the dam, but the particular operations are made subject to any changes which the engineer may choose to make, in the interest of a more effectual mixing or compacting of the materials. The general drawings show the probable depth to which the puddle wall will be carried, but the depth shown is not to be considered as exact nor final, as it may be varied according to the character of the ground developed by the excavation.

All that part of the dam on the up-stream side of the core wall shall be made of such clay material as the engineer may select from that overlying the gravel stratum in the immediate vicinity below the dam. It is thought that at least half of this overlying clay is suitable for this purpose. It shall be thoroughly incorporated with the upper clay underlying the dam by first plowing up the surface, after the top soil has been removed, and rolling down again as described below. This plowed upper surface, and also the clay fill, shall be pulverized in courses not over 6 inches thick, by harrowing or rolling, or both, before wetting down. It shall then be wet down thoroughly and allowed to stand until it is in a proper condition for most effectual compacting. It shall then be rolled to the satisfaction of the engineer, and in accordance with his directions,

with a grooved roller weighing not less than 150 pounds per lineal inch of roller, measured along its axis.

All that part of the dam below the puddle core wall shall be filled with the surface clay in the immediate locality below the dam. It shall be laid in courses not over 6 inches in thickness, harrowed and rolled dry to the satisfaction of the engineer. It is the intention to make as compact a mass of this portion as possible without wetting down. J. & F.

**127. Specifications for Coffer-Dams.** The following specification for the construction of coffer-dams, and for the methods of paying for the same is taken from a recent United States Engineer Corps specification for the building of a navigation lock and dam on the Great Kanawha River, West Virginia. It illustrates how such specifications may be drawn and the work paid for in an equitable manner, and how bids may be made up upon such work without assuming extraordinary risk, and without knowing much of the nature of the material to be excavated or of the depths to which the construction will extend:

*How Built.*—The coffer-dams will be built as shown generally by the drawings exhibited and as directed by the engineer. They will be formed of cribs sunk to hard pan, sheathed with plank and filled with heavy-dredged river-bed material not liable to wash. They will be thoroughly banked on the outside with clay puddling, or like material, of quality and quantity to make them sufficiently water-tight to be pumped out. The crib-filling and the banking outside will be protected to such an extent, as directed, by a top layer of loose stone.

As the work within the different sections of the coffer-dams for the dam is finished, the ends of the next section of coffer will, when required, be made of square sawed timber, rods, upright plank and puddle, built across and near the end of the finished part. Similar timber and plank bulkheads will, also, if ordered, be built by the contractor between the coffer-dam for the lock and the lock wall, to form part of the first section of coffer-dam for the navigation pass and elsewhere in making coffer connections as the engineer may require.

*How Paid For.*—The United States will pay the contractor for the dredging and excavation for the site of the coffer-dams his contract price for "excavation." For logs and sheathing used, he will be paid his contract prices for "crib-logs in coffer-dam" and "sheathing." For material used to fill the coffer-dam cribs, he will be paid his contract price for "coffer-dam

filling." The plank and sawed timber used in the coffer-ends or bulkheads will be paid for as "sheathing," and the puddle in same as "coffer-dam filling." It is understood that all labor, all banking, puddling and stone used on the outside of the cribs, the spikes and bolts and all material not mentioned, required in the construction of the coffer-dams, shall be furnished by the contractor without cost to the United States. The coffer dams must be promptly banked to full height. No payment will be made for logs or filling above the level of the top of the lowest part of unfinished banking. No payment will be made for any coffer-dam materials carried off by the river or lost in any manner during construction. All repairs to the coffer-dams or their adjuncts must be borne by the contractor.

*Removal.*—The contractor will be required to remove the coffer-dams and their belongings at his own cost. The time and manner of the removal of the coffer-dams, or any parts of them, and the place to deposit the materials, to be prescribed by the engineer.

*Ownership.*—It is understood and agreed that the payments for excavation, logs, sheathing and filling, as provided for above, shall cover the entire cost of the coffer-dams to the United States, and by virtue thereof they shall become the property of the United States, in case of the failure or annulment of this contract.

*Dredges and Pumps.*—In building the coffer-dams the contractor will be required to employ, at the same time, not less than two suitable steam dredges at excavating and filling; and for pumping the coffer-dams he must keep at least three good sufficient pumping outfits, with pumps, engines and boats complete, in, or always ready for, operation. The dredges must be equipped to do effective work to a depth of 28 feet.

W. P. C.

**128. Specifications for Protective Work.** It is customary for engineers to require the contractor to protect his work from all causes, such as landslides, rainfall, floods, ground water, quicksand, etc., without any special compensation therefor. In all such cases the contractor, of course, will build his temporary protective works as cheaply as possible, and often will not provide that degree of protection which the engineer may think is necessary and wise. A fair division of the responsibility and cost of such protective works between the contractor and the owner is therefore desirable, and the following specifications taken from those used on the new Croton Dam of New

York city, in 1892, are offered as a very excellent solution of this problem.

It will be noted that the cost of such protective works as the engineer might consider necessary is to be paid for by the city at the standard prices per unit of measure named in the bid, and the engineer is given control of the design and general character of such works. The responsibility for the efficient execution of such works, however, is made to rest upon the contractor by holding him responsible for all damages caused by their inefficiency, except in one instance of an unprecedented flood in the Croton river, in which particular case the damages are to be duly appraised and paid for by the city.

It will also be noted that the taking care of the ground water by pumping, rests wholly upon the contractor without special compensation.

The contractor shall do all other work needed to protect his work from water; he shall erect all temporary dams, coffer-dams, sheet piling and other devices, take care of the river, and shall be responsible for all damage that may be caused by the action of water, whether from negligence or any other cause. Such damage is to be repaired, and the work must be restored and maintained at his cost.

All earth and rock excavation, masonry, timber and other work, temporary or permanent, for the purpose of protecting the work from the river, provided that they are ordered or approved by the engineer, are to be paid for at the prices stipulated in this contract. All work of this character is to be removed by the contractor at his own expense, if so ordered by the engineer.

The responsibility of the contractor as to damage caused by the inefficiency of the protective work shall cease, however, if such damage is caused by the river at a time when the flow of the river attains such volume as will cause it to rise to a height of more than eighty-one inches above the stone crest of the present Croton dam, such height being the greatest recorded by the city authorities.

Such damage as may be caused under the circumstances just stated shall be repaired by the contractor as soon as practicable, under the direction of the engineer, who shall appraise the cost of such work of repairs, and the amount of the same shall be paid to the contractor on the certificate of the engineer that the work has been completed to his satisfaction; and, after

such certificate shall have been issued, the contractor shall again become responsible for all damage that may be caused by the action of the water, in the same manner as is specified above.

If such appraisal of the engineer is not satisfactory to the contractor, the said contractor shall so state in writing to the aqueduct commissioners, and, thereupon, a board of arbitration, composed, first, of the chief engineer, or of such other person that the aqueduct commissioners may designate; second, of a person selected by the contractor; third, of another person to be designated by the other two, shall proceed to appraise the cost of such damage, and their decision shall be final and binding on both parties, provided it is the unanimous decision of the three members of the said board; but if the said decision is not unanimous, the appraisal of the chief engineer shall stand and become final and binding to both parties.[1] And, on the certificate of the aqueduct commissioners that the said appraisal has been made in accordance with the stipulations of this agreement, the amount of said appraisal shall be paid to the contractor. And the said appraisal, whether made by the chief engineer or by the said board of arbitration, shall include only the cost of the actual work done to repair the damage, and shall not include any alleged loss of profit or other loss due to the delay caused by such repairs, but an extension of time shall be granted to the contractor for the performance of his contract, equivalent, in the opinion of the engineer, to the loss of time due to the interruption of the operations of construction on account of the said work of repairs.

The contractor is to do all the draining and pumping which shall be necessary for keeping the work free from water, and if at any time the engineer is of the opinion that, in order to maintain the slopes and sides of the excavations in proper order, it is necessary to remove the water from the ground outside of the limits of the excavations, the contractor shall, at his request, sink the necessary pipes or wells to intercept the water, and place, maintain and work such pumping or other exhausting apparatus as shall be sufficient to properly maintain the said slopes and sides.

The cost of furnishing the necessary appliances and machinery, of working them, and of doing all the work connected with draining and pumping operations, is to be included in the prices bid for the various kinds of work which the draining and pumping operations are intended to protect. A. F.

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[1] This is a new departure in arbitration proceedings, but it has many things to recommend it. AUTHOR.

## SPECIFICATIONS FOR CEMENT MORTAR, CONCRETE, AND MASONRY.

(For U. S. Engr Corps Specifications, see Appendix B., page 515.)

129. **Cement Mortar.**[1] There are in general two kinds of cement in common use in America, namely, Portland or artificial cement and natural cement. Portland cement is an artificial mixture of lime and clay properly burned and ground. Natural cement is made by burning the natural rock which contains approximately the proper ingredients, and grinding the calcined product. Portland cements are known by their various manufacturer's names or brands, and are mostly imported from Germany, France and England. Recently a number of manufactories have been established in America. Natural cements are usually known under a geographical name, indicating their place of manufacture, as Rosendale cement, made on the Hudson river; Louisville cement, made on the Ohio river in the vicinity of Louisville; Utica cement, made at Utica in the northern part of the state of Illinois; Milwaukee cement, etc. In general the Portland cement costs about three times as much as the natural cements and it has three or four times the strength of these. It is common to require a tensile strength of from 300 to 400 pounds per square inch for Portland cements, which have hardened one day in the air and six days in water, and about 100 pounds per square inch tensile strength for natural cements, similarly treated. The Louisville cement is quick setting, and a very fair test may be obtained of its strength in twenty-four hours, in which case a tensile strength of from 60 to 80 pounds per square inch may be specified, the briquettes being allowed to remain one hour in the air, and twenty-three hours in water.

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[1] The reader is referred to the author's work on *The Materials of Construction* (J. Wiley & Sons, New York), for an extended description of the methods of manufacture of the different kinds of cement, the theory of their setting and hardening, the standard methods of testing cements and mortars in this and in other countries, and various proposed improvements in these methods. The manufacture of Portland cement has increased so rapidly in America within the last few years that it would seem we would soon be able to make all we require. The quality of the American cement is also fully up to that of the best foreign brands.

The strength of cement and cement mortar depends greatly on the fineness of the cement. This is usually tested by passing it through a sieve of from 50 to 100 meshes per lineal inch, having from 2,500 to 10,000 meshes per square inch. The 100 mesh sieve is much to be preferred, and is usually specified in the case of Portland cement, since probably only the particles which would pass through such a sieve are really efficient or active in the process of hardening, the coarser parts being inert, or as so much sand.[1]

A cement mortar is a thorough mixture of sand with cement, first in a dry state, usually in the proportion of one of cement to two of sand by measure, with natural cements, and one of cement to three or four of sand when Portland cement is used. After these ingredients have been effectually mixed, sufficient water is added to reduce the composition to the desired consistency. It is important that the sand should be clean, or free from all earthy ingredients. It is common also to specify that it shall be sharp; that is to say, the grains should not be too much rounded. Ocean beach sand is apt to be very much worn, and not sharp in this sense. River or bank sand is usually preferred on this account.

In specifying the proportions of sand and cement to be used in making up a cement mortar, it is customary simply to name so many parts of sand to one part of cement, by measure. It would, as a rule, be inconvenient to determine this ratio by weight, but a determination by measure is subject to serious objections. For instance, a barrel or original package of cement, when dumped or turned out upon a mixing platform in a loose and fluffy condition will have nearly 50 per cent. more volume than it had in the original package. *It is necessary, therefore, in order that the meaning of the specifications shall be clear, to indicate whether the proportions by volume shall be taken with the cement in the original package, or in a loose state, after having been emptied from such package.* It is perhaps more convenient to measure the cement after it has been emptied from the original package. *In any case the engineer*

[1] It is now known (1898) that only those particles of cement which are impalpable dust, and finer than can be tested by any sieve, are the active portions in the process of hardening. The grains of sensible size simply serve as so much sand.

*should decide which method he proposes to adopt, and reveal this decision in the specifications themselves.* It is not sufficient to say that one barrel of cement shall be used for so many barrels of sand, thinking thus to have the cement measured in the original package, since American cement is commonly delivered in sacks, and to get it into a barrel it would require the measurement of the cement in a loose condition. One barrel or four bags of cement may be taken as equal to four cubic feet in volume. The following specification for the making of cement mortar is satisfactory in every respect, except that it does not indicate whether the cement is to be measured in the original package, or in a loose condition:

Mortar shall be composed of one measure of cement and two measures of sand, and shall be mixed on a tight platform as follows: One measure of sand shall be evenly distributed on the platform; and one measure of cement shall be distributed on the sand, and a second measure of sand shall be distributed on the cement. The sand and cement shall then be thoroughly mixed in a dry state, being turned over with shovels until this is accomplished. Water shall then be added in a sufficient quantity to convert the sand and cement into a mortar which will stand in a pile and not be fluid enough to flow. During the application of the water the mass must be constantly turned with shovels, so that the mortar will be of uniform consistency.

O. B.

For determining proportions of cement and sand the following specifications of the Boston waterworks is recommended:

In preparing mortar and concrete, the cement, sand and stone shall be mixed in the proportions by volume herein specified. The cement shall be measured when so compacted that 300 pounds of dry natural cement or 380 pounds of dry Portland cement have a volume of 3.6 cubic feet. The sand and stone shall be measured when not packed more closely than by throwing them in the usual way into a barrel or box.

**130. Cement Concrete.**[1] Cement concrete is usually composed of cement mortar as described in the previous article, mixed with broken stone. It may, however, be composed of cement mortar mixed with gravel. If gravel can be procured free from earthy matter, varying in size from coarse sand to

[1] For complete specifications for a Concrete and Steel Bridge, by Edwin Thatcher, see Engineering News, September 21, 1899, p. 184

stones not more than about two inches in diameter, it would serve a better purpose in the manufacture of concrete than does broken stone. Experiments have shown also, that when stone is broken in a stone crusher and not screened, so that all the finer parts remain in, including the stone dust, a stronger concrete results than with the use of the same quantity of screened stone.

The ideal cement concrete is such a mixture of material of graded size, from the largest used down to the finest sand, as will make a nearly solid mass, when properly mixed. This may then be solidified by uniting with it such an amount of finely ground cement as will serve to completely coat each and every particle of sand, gravel, or stone, and fill the small voids remaining after the graded materials have been thoroughly and uniformly mixed. Since crushed rock is always angular it will be often impossible to make as solid a concrete mass with it as can be made by the use of gravel. When gravel is used it is best to have it screened to a series of regularly graded sizes, and then such proportions of each successive smaller size used as will serve to fill the voids in the larger size. The cement finally fills the voids between the small sand grains.

The sand and cement should always be very thoroughly mixed dry, then the coarser material should be thoroughly wet and the excess of water drained off, after which the mixed sand and cement should be incorporated with the moistened gravel or rock, and a sufficient amount of water added while the mixing is in progress as will reduce the entire mass to the proper consistency. The most effectual mixing can be done by machinery, but it is more commonly done by hand. Perhaps the best cement mixer is a cubical box mounted on trunions at its diagonally opposite corners into which the proper proportions of the constituent parts, including the water, are placed and the whole given a certain number of revolutions. There are various kinds of continuous mixtures into which the proper proportions of the several ingredients are thrown somewhat at random, and from which the concrete is supposed to continuously fall upon the work in a properly mixed condition. This

method is probably fully equal to hand mixing, but is not as satisfactory as the use of the cubical box above described.

Concrete should always be laid in courses of from six to nine inches in depth, and thoroughly rammed in place in order to compact it effectually. If several courses are to be laid in order to obtain the required depth of concrete, *one course should follow another as rapidly as possible,* in order that they may become effectually joined, and form finally one monolithic mass. *The amount of water should be just sufficient to cause it to flush to the surface by hard ramming.* When the work is interrupted at the end of a day, and other courses of concrete are to be laid the following day, and especially when Sunday intervenes, the top of the concrete should be covered and kept wet, and when the next course is laid the top surface of the former should be thoroughly water-soaked, and all earthy matter removed from it.

Masonry or other heavy weights should not be laid upon concrete until it has been allowed to harden, usually as much as twenty-four hours. In the case of quick setting natural cements, however, twelve hours may be sufficient.

Since successive freezing and thawing will prevent the ultimate hardening of cement mortar, it is customary to prescribe that no masonry or concrete in which cement mortar is employed shall be laid in freezing weather. It is a well established fact, however, that Portland cement mortar is not injured by freezing if it remains in a frozen condition for a considerable length of time. Again, when the temperature is not too low, but below freezing, freezing of the mortar may be prevented by adding salt to the water in making the mortar, or the ingredients of concrete may be heated so that the concrete will have set before freezing can take place.

The following specification for cement concrete includes as a constituent part of it the specification for cement mortar in the previous article. That which is given below is supposed to follow directly upon the previous quotation, the whole constituting a specification for cement concrete:

The broken stone shall be wetted down and then thoroughly mixed with the mortar by turning it over with shovels: no

more stone shall be used than can be covered on all surfaces with mortar, and the proportion of broken stone in the concrete must not exceed five measures of stone to one measure of cement. All material must be actually measured in bulk.

Concrete must be mixed in small and convenient quantities and immediately deposited in the work. It must be carefully placed, and not dropped from any height. It shall be laid in sections, and in horizontal layers not exceeding nine (9) inches in thickness, and it must be *thoroughly rammed* until the stone is covered with mortar and a film of water appears on the surface. In no case shall concrete be permitted to remain in the work if it has begun to set before the ramming is completed. When concrete is properly made the whole mass becomes one stone when it has set, and it is very important that it shall be deposited continuously in the work. All surfaces upon which concrete is to be laid must be wetted before the concrete is deposited. Plank or timber forms must be provided when necessary to confine the concrete to the shape and dimensions shown on the plans.

Before any weight is placed on concrete it shall have as much time to set as can conveniently be allowed, and in no case less than twelve (12) hours.

In cold weather material for concrete shall be heated as directed by the engineer.

The engineer will issue special instructions for concrete which is to be deposited under water. O. B.

The following method[1] of making concrete by using sea-washed gravel of standard sizes as obtained from graduated screens has given most excellent results. In this mixture there were three grades of sand and gravel employed, namely, fine sand, coarse sand, and small gravel stones up to one-fourth of an inch in diameter, and large gravel from one-half to two inches in diameter. The proportions were one part cement, two parts fine sand, four parts coarse sand and small gravel, and eight parts of the larger gravel, making in all one part of cement to fourteen parts of sand and gravel, by measure. The cement and fine sand were mixed dry. The two grades of gravel were then thoroughly mixed and saturated with water, the surplus water being allowed to drain off. The dry mixture of cement and sand was then uniformly spread over the wet gravel and thoroughly mixed with it. The water which remained adhering to the gravel was found sufficient to

[1] See article by C. H. Platte, C. E. in Engineering News of February [illegible]1, 18[illegible]5.

moisten the cement, and also to insure a uniform distribution of such water through the mass. The mixture was then deposited in place and thoroughly rammed, and it was found to give a very solid and strong concrete. It was found that three and one-half barrels of cement were used for each four and one-half cubic yards of concrete in place. It is said that the concrete was equal in every particular to that made of one part of cement, three parts sand, and five parts broken lime stone. This species of concrete was used in the foundations of the New York and Brooklyn bridge, and also on some of the New York city cable railways. This mixture comes very near being the ideal concrete for both solidity and economy.

The following specification for "cyclopean masonry" was used by the Jersey City Water Supply company in 1902 for the building of a concrete masonry dam. The author regards this as an ideal specification for monolithic construction in large masses. The cement was furnished by the owner; the practice enables the engineer to vary the mixtures and the proportions at pleasure.

*Cyclopean Masonry* shall be used for substantially the whole of the dam including the cut-off walls and the overflow channel to the end of the curve, but not including the exposed downstream face of the dam and overflow. This masonry shall consist of the largest rubble stones which can be gotten out and handled economically from the quarry, laid in cement mortar or concrete, the *cement being furnished by the company.*

Large and well shaped stones shall be selected for the upstream face of the dam and for the downstream face of the dam below grade 244.5. These stones shall be laid in full beds of rather wet mortar, care being taken that it fills all spaces. All stones shall be jarred into position and shall not be raised after once being placed; smaller stones, or spalls, may be embedded in the mortar to fill up large spaces and to prepare the bed for the largest stones. All stones shall be well bonded, one-third being headers extending at least four feet into the wall.

All exposed joints shall be flushed full of mortar and afterwards raked out to a depth of two inches and pointed with neat Portland cement.

The interior portion of the dam shall be laid with large blocks of irregular shaped rubble embedded in concrete; this concrete shall be composed of cement, stone and ballast as above specified, and of proportions to be determined. The

outside stones of the dam shall be kept built higher than the inside; concrete shall then be mixed very wet and dumped in a low spot; large stones shall then be lowered as close as practicable together into this soft concrete and allowed to settle to place, care being taken to see that all joints are filled. Light rammers shall be used to joggle the concrete and insure its flowing into all cracks and crevasses and making an absolutely monolithic mass.

No trowel work will be expected or allowed on the interior masonry of the dam.

The stones may be as irregular in dimensions and shape as the quarry can provide, but care shall be taken to secure a good bond and break joints, both vertically and horizontally, and good judgment shall be exercised in distributing the larger stones in equal proportion to all parts, and the longer stones as binders.

In spaces large enough to admit a smaller stone being embedded in the concrete, this shall be done; the object being to secure a monolithic mass of stone and concrete, with as large proportions of stone as it is possible to secure, and a wall as nearly impervious to water as it is possible to make it.

The price of cyclopean masonry shall include the furnishing, loading, transportation, and laying of the stone, ballast and sand, the mixing of the concrete, the handling of the cement *which will be furnished by the company,* and all labor and material necessary to complete the work as above specified.

R. H.

When concrete is used for the purpose of making a wall impervious to water, it must be made of small gravel or small broken stone, and it must be unusually rich. That is to say a large excess of mortar must be employed. With these precautions, with proper care in laying, it is possible to make a practically water-tight wall of cement concrete. Such a wall or partition may be constructed between two rubble stone walls, the concrete core being relied on to make the wall practically water-tight.

**131. Specifications for Stone.** The following specifications for stone to be used for various purposes are those in use by the Chicago, Milwaukee & St. Paul Railway. While certain qualities of stone are here specified, no method is prescribed for determining these qualities. The qualities of building stone are often examined by means of laboratory tests for strength, specific gravity, and for effect of freezing, and also

by chemical and microscopic tests to determine composition and structure. While such tests have considerable value in the absence of any knowledge from experience, they do not take the place of that kind of knowledge which is obtained from having observed the strength and weathering qualities in actual structures which have been long exposed to the action of the elements. It is always desirable, therefore, to have stone from quarries of established reputation, the products of which have long been upon the market. For this reason where stone specifications are prepared for a given locality, the engineer may inform himself of the most available kind of stone to be used at that place, and may specify two or three alternative varieties, by naming the quarries. Evidently this would not be practicable where general specifications are prepared for an entire railway system of such large extent as that of the Chicago, Milwaukee & St. Paul. For this system the specifications read as follows:

*Stone.*—Bridge, block rubble and common rubble stone must be of sound and durable quality, free from flint seams, powder cracks, dry and incipient cracks, flaws and other imperfections, and of such character as will resist the action of the weather without injury to the masonry in the climates traversed by the railway company's lines.

All stone, except riprap, shall have its top and bottom beds approximately parallel to each other and to the natural quarry beds, and shall be approximately rectangular in shape with sides perpendicular to its beds.

Bridge stone shall be from 14 inches to 24 inches thick, from 4 feet to 7 feet long, and from 2 feet to 5 feet wide; but in no case shall its length be less than two and one-half times its thickness, nor its width be less than one and one-half times its thickness.

Block rubble stone shall be from 8 inches to 14 inches thick, 2 feet to 5 feet long, and not less than 18 inches wide.

Common rubble stone shall not be less than 6 inches thick, 16 inches long, and 10 inches wide.

Riprap must be of sound stone of such quality that will not disintegrate under the action of the weather. It shall be of random size and shape, none to be less than 20 pounds in weight, and the majority such as can be handled by one man, but no stone to be larger than can be handled by two men without the use of a bar.

The engineer reserves the right to specify the quarry and the particular ledge in the quarry from which the stone shall be supplied.

The stone may be inspected before or after shipment from the quarry, at the option of the railway company, and in the former case the contractor shall furnish the inspector with full facilities for examination of the stone.

The engineer reserves the right to accept or reject any or all of the stone for want of conformity with these specifications at any time previous to its being paid for in full by the railway company, notwithstanding that it may have been previously passed upon by the inspector, and in case of such rejection the title to the stone shall be in the contractor, and he shall be charged freight on the same at regular tariff rates. O. B.

132. **Stone Masonry.** It is not safe for the engineer to undertake to designate a particular class of masonry by a particular name, without entering in the specifications a full description of the same. The names of classes of masonry are too indefinite and are used in too many senses to make it safe to pursue such a course. The engineer should, therefore, describe in considerable detail exactly the kind of masonry construction he desires, and he need not give to such masonry any particular class name. If he does use class names, he should define them clearly in the body of the specifications. Specifications will be given below for several different kinds of masonry.

In laying masonry and in writing the specifications for the same, three particular ends should be constantly in mind. These are: (*a*) evenness and equality of bearing in supporting the superimposed load; (*b*) so far as possible an entire absence of voids or openings in the body of the work; and (*c*) so effectual a bonding of the mass as to cause it to act so far as possible as a monolithic structure. If the masonry occupies a prominent situation so that its appearance is a matter of importance, the exterior surfaces may be made to conform to any desired plan. The following specifications are thought to be self-explanatory. They are the general specifications for bridge masonry used by the Chicago, Milwaukee & St. Paul Railway. While these specifications do not require a very expensive grade of work, if fairly carried out they will produce

permanent monolithic structures of great strength, provided a good quality of stone and cement have been employed, the specifications for which are issued separately.

*Bridge Masonry.*—All masonry shall be built according to the plans and instructions furnished by the engineer, and when built by contract will be measured, estimated, and paid for by the cubic yard, and only to the amount of cubical contents of the same as planned and laid out.

All masonry built by contract shall be subject to the supervision of an inspector whose duties it shall be to see that the requirements of these specifications are complied with, but his presence shall in no way or in any degree lessen the responsibility of the contractor or his obligations.

The stone used in bridge masonry shall be of the quality and dimensions described and known as bridge stone in this company's specifications for stone.

The stone shall be carefully cut and dressed, forming headers and stretchers, which must be laid in regular horizontal courses in good cement mortar, with beds and builds level, the end and side joints vertical and broken at least fifteen (15) inches.

All foundation or footing courses must be made of select large stones not less than eighteen (18) inches in thickness and having a superficial area of at least fifteen (15) square feet.

No course of stone shall be less than fourteen (14) nor more than twenty-four (24) inches in thickness and each course shall be continuous around and through the wall, the courses decreasing, when at all, regularly in thickness from the bottom to the top of the wall.

Face stones shall be composed of headers and stretchers, and each stone in any course shall be of the exact thickness of the one adjoining it. The outer surfaces are to be rock face, but the edges shall be brought to lines corresponding to the finished dimensions of the masonry, and there shall be no projections of over four (4) inches beyond these lines.

The beds and joints of face stone shall be dressed back at least twelve (12) inches from the face of the wall and must be brought to a joint of not more than one-half (½) an inch when laid. The under bed must extend to the extreme back of the stone; *no overhang* whatever will be allowed.

Stretchers shall not be less in length than two and one-half (2½) times their height, and no stone shall have a less width than one and one-half (1½) times its thickness.

Headers at least four (4) feet long, when the thickness of

the wall will permit, shall be put in frequently to bond the wall, and they shall be so arranged that the headers of any course shall fall between the headers of the course immediately below it. There shall be one header to every two (2) stretchers, and they shall, as far as practicable, hold the size back into the heart of the wall that they show in the face.

When the walls do not exceed four (4) feet in thickness headers must run entirely through the wall, and in pier work a number of them shall extend through, even though the walls are of a greater thickness than this.

When walls exceed four (4) feet in thickness, there shall be as many headers of the same size in the back of the wall as in the face, and so arranged that a header in the rear of the wall shall be between two headers in the front.

The backing and interior of the walls shall be of large, well shaped stone of a thickness equal to that of the corresponding face stone. No voids over six (6) inches in width shall be left between these stone, and all such void must be filled with small stones and spalls thoroughly bedded in cement mortar or grouted. When the masonry is completed, it must contain no voids, and must be, as nearly as practicable impervious to water. When weep holes are necessary, they will be ordered by the engineer.

All stones shall be prepared by dressing and hammering before they are brought on the wall, and must be so shaped that their bearing beds will be parallel to their natural beds. No heavy hammering will be allowed on the wall after a course is set, and should any irregularities occur, they must be carefully pointed off.

Each stone must be laid on its broadest bed without the use of chips, pinners or levelers, in a full bed of mortar, so that no stone shall bear upon another stone at any point without a mortar joint intervening.

Care must be taken not to injure the joints of stone already laid. Should a stone be moved or the joint be broken the stone must be taken out, the mortar thoroughly cleaned from both the stone and the masonry and the stone then reset.

The stones in each course shall be so arranged as to form a proper bond with the stones of the course immediately beneath it, and in no case shall this bond be less than fifteen (15) inches.

Both the stone and the masonry must be kept free from all dirt that will interfere with the adhesion of the mortar or cement to the stone, and in warm weather the stone and the masonry must be wet with clean water just before laying.

When masonry is built in freezing weather, the masonry

and stone must be thoroughly freed from ice or frost by using salt and hot water, and where practicable, the stone must be held over a fire just before being set.

The top surfaces of coping stones of abutments and piers are to be rough cut to a true plane, and the surfaces where the bed plates of iron bridges rest shall be bush hammered and made level. When the track is on a grade or curve, the elevation both for the curvature and grade will be provided for in the ironwork. Under no circumstances will the masonry be cut on an incline for this purpose.

The front face and top of all mud walls shall be rough cut to a true plane.

Whenever it may be necessary to remove any part of the present masonry in extending abutments or piers for second track work, it shall be stepped back so as to insure a sufficient bond between the new and the old work, so as to break joints nowhere less than twelve (12) inches. O. B.

The following specifications for different classes of masonry are taken from the standard specifications used by the Pennsylvania Railroad Company. In these specifications three separate classes of masonry are recognized, and for any particular piece of work, it becomes necessary to specify only the class of masonry which shall be used in these general specifications:

Detailed plans will be prepared by the engineer for each structure, and copies of the same furnished to the conaractor before the commencement of the work. All stone used for the different classes of masonry must be sound, durable and not liable to be affected by the weather, and shall be subject to the approval of the engineer.

Masonry will be classified as follows:

*First-class bridge masonry* shall consist of ranged rock work of the best description. The face stones shall be accurately squared, jointed and bedded, and laid in regular horizontal courses, not less than twelve inches in thickness, decreasing regularly from bottom to top of the walls. They shall consist of headers and stretchers, and there shall be at least one header to every two stretchers, and they shall be so laid that, as nearly as practicable, the headers in each course shall divide equally, or nearly so, the spaces between the headers in the course immediately below. Stretchers shall be not less than three feet long and sixteen inches in width. Headers shall not be less than three feet in length and eighteen inches in width, and shall hold the size back into the heart of the wall that they show in the face.

When the walls do not exceed four feet in thickness the headers shall run entirely through, and when they exceed that thickness there shall be as many headers of the same size in the rear as in the front of the wall, so arranged that a header in the rear of the wall shall be between two headers in the front.

Every stone must be laid on its natural bed, and all stones must have their beds well dressed and made always as large as the stone will admit of. Mortar joints shall not exceed one quarter inch in width; the vertical joints of the face must be in contact at least four inches, measured in from the face, and as much more as the stone will admit of. The stone will be cut with pitched edges, but all corners, batir lines, steps and copings must be run with a neat chisel draft of one and one-half inches on each corner, and the projections of the rock face must not exceed three inches beyond the face of the pitch or draft lines of the stones. The stones of each course shall be so arranged as to form a proper bond with the stones of the underlying course, and the bond shall in no case measure less than one foot. Stretchers shall in no case have less than sixteen inches bed for a twelve inch course, and for all courses above sixteen inches in thickness, at least as much bed as face. The whole of the masonry shall be laid in cement mortar, each stone being carefully cleaned and dampened before setting and each course shall be thoroughly cemented before the succeeding course is laid. No hammering on the wall will be allowed after the course is set; if any irregularities occur they must be carefully pointed off. The backing shall consist of stones with beds dressed to one-half inch, and of a thickness equal to that of the corresponding face stones; they shall be laid in full cement mortar beds, so as to break joints and thoroughly bond the work in all directions, and on the completion of each course the space between the large backing stones (none of which spaces will be over six inches wide) shall be filled with small stones and spalls, thoroughly bedded in cement mortar or grouted.

All foundation courses must be laid with select large stones not less than eighteen inches in thickness, nor of less superficial surface than fifteen square feet. All bridge seats, steps and tops of walls should be finished with a coping course of such dimensions and projection as may be ordered by the engineer, dressed and cut to a true surface on top and on the showing faces and in conformity with diagrams for the same, which shall be furnished by the engineer. If required, all copings shall be fastened together with clamps of iron.

*First-class arch masonry* shall be built in all respects in accordance with the above specifications for first-class bridge masonry. The ring stones shall be dressed to such size and

shape as the engineer may determine, and of the thickness shown on the plans. The joints must be made on true radial lines, and the face of the sheeting stones must be dressed to make close joints. The ring stones and arch sheeting stones shall break joints not less than one foot. The wing walls shall be neatly stepped in accordance with the drawings furnished, with selected stones the full width of the wing and not less than fourteen inches thick, and no stone shall be covered less than twelve inches by the one next above it.

The parapets shall be finished with a coping course of full width of parapet, with such projection as may be directed by the engineer; the coping to be not less than fourteen inches thick and to be fastened together with wrought iron clamps.

*Second-class bridge masonry* shall consist of broken or random range work of the best description. The face stones shall be dressed to a uniform thickness throughout before being laid, but not hammered, and shall be laid with horizontal beds and vertical joints on the face. No stone shall be less than eight inches in thickness, unless otherwise ordered by the engineer. There shall be at least one header to every three stretchers, and both headers and stretchers shall be of similar size, when the thickness of the wall will admit, but neither shall be less than three feet in length and fifteen inches in width. The same arrangement of headers shall be required as is specified for first-class bridge masonry. Mortar joints shall not exceed one-half inch in thickness. All corners and quoins shall have hammer-dressed beds and joints. All corners and batir lines shall be run with an inch and a half chisel draft. The vertical joints of the face must be in contact at least four inches, measured from the face, and as much more as the stone will admit of. The work need not be laid up in regular courses, but shall be well bonded. The stones shall be cleaned and dampened before setting and shall be laid in cement mortar. The backing shall consist of stones of the same thickness as the adjacent face stone, laid in full cement mortar beds with good joints and bonds, and the spaces filled with spalls, thoroughly bedded in cement mortar, or grouted, as specified for first-class bridge masonry. Bridge seats, steps and tops of walls shall be coped in the same manner as specified for first-class masonry. Stones in foundation courses shall be of not less than twelve inches thickness and ten square feet of surface.

*Second-class arch masonry* shall be laid in cement mortar, and shall be of the same general character and description as second-class bridge masonry, with the exception of the arch sheeting, for which proper stones shall be selected that shall have a good bearing throughout the thickness of the arch, and shall be well bonded and be of the full depth of the arch. No

stone shall be less than six inches in thickness on the intrados of the arch. The ring stones of all arches shall conform to the specifications for first-class arch masonry.

*Third-class masonry* shall be laid dry, or in lime or cement mortar as may be directed by the engineer. It shall be formed of good quarry stones, laid upon their natural beds, and roughly squared on the joints, beds and faces, the stones breaking joints at least six inches, and with at least one header for every three stretchers. No stone shall be used in the face of the wall less than six inches in thickness, or less than twelve inches on the least horizontal dimensions. Headers shall be at least three feet long, or extend entirely through the wall. The ends of all walls shall be dressed and finished in accordance with the plans. The stones in the foundations must not be less than ten inches in thickness, and shall contain not less than ten square feet surface, and each shall be firmly, solidly and carefully laid.

In box culverts the top courses of the side walls shall extend entirely across the walls, and the covering stones shall have a bearing of at least one foot on each wall. The thickness of covering stones shall not be less than ten inches for two feet openings; not less than twelve inches for three feet openings, and not less than fifteen inches for four feet openings. Unless built on timber foundations reaching entirely across the opening, the space between side walls of box culverts must be paved with stone, set on edge, not less than eight inches deep, and well secured at the ends with deep curbing. P. Ry.

**133. Specifications for Stone Masonry for a Large Stone Dam.** The following specifications for stone masonry are those which were used in the construction of the new Croton dam, New York city, 1892. They are commended especially for their securing a most efficient, solid, and impervious grade of work, at a minimum cost. Thus the body of the dam, composed of rubble stone masonry laid in cement mortar, thoroughly bonded, and made entirely solid, cost from \$3.40 to \$4.00 per cubic yard, the cement mortar being one of Rosendale cement to two of sand, the stone having to be hauled about one mile.

Another significant feature of these specifications is the paying for the face dressing per unit of surface in addition to the standard price per cubic yard, the matter of this face dressing being left until the work is executed. In this way such small

details need not be determined in advance and indicated upon the drawings.

*Stone Masonry.*—All stone masonry is to be built of sound, clean quarry stone of quality and size satisfactory to the engineer; all joints to be full of mortar, unless otherwise specified.

Dry rubble masonry and paving are to be laid without mortar, and are to be used for walls, for the slopes of the dam embankments, and at any other place that may be designated.

This class of masonry is to be of stone of suitable size and quality, laid closely by hand with as few spalls as practicable, in such manner as to present a smooth and true surface. The work is to be measured in accordance with the lines shown on the drawings or ordered during the progress of the work. The stones used must be roughly rectangular; all irregular projection and feather edges must be hammered off. No stone will be accepted which has less than the depth represented on the plans or ordered. Each stone used for paving must be set solid on the foundation of broken stone or earth and no interstices must be left.

In the dry rubble masonry walls, large stones must be used, especially for the faces, and the walls must be bonded with frequent headers, of such frequency and sizes as shall be approved by the engineer.

Riprap may be used in connection with the protective work, and wherever the engineer may order it. It shall be made of stone of such size and quality and in such manner as he shall direct, and must be laid by hand.

After the slopes which are to receive the paving have been dressed, a layer of broken stone is to be spread as a foundation for the paving, wherever ordered. The broken stones must be sound and hard, not exceeding two inches at their greatest diameter. Broken stone, not exceeding one inch in diameter, may be used for forming roadways; it is to be spread to such thickness as ordered and heavily rolled or rammed. Broken stones may be used also wherever the engineer may direct, rolled if so directed, and paid for under this head, except the broken stone used for making concrete, the cost of which is included in the price hereinbefore stipulated for concrete laid.

Rubble stone masonry is to be used for the central part of the dam, for the overflow, for the center walls of the earth embankments, for most of the structures and appurtenances of the dam, and wherever ordered by the engineer.

Rubble stone masonry shall be made of sound, clean stone of suitable size, quality and shape for the work in hand, and presenting good beds for materials of that class. Especial care must be taken to have the beds and joints full of mortar, and

no grouting or filling of joints after the stones are in place will be allowed. The work must be thoroughly bonded. The faces of the rubble stone masonry, especially the up-stream face of the walls, shall be closely inspected after they are built, and if any mortar joints are not full and flush, they shall be taken out to a depth of no less than three inches or more, if so ordered, and repointed properly.

A large quantity of rubble stone masonry in mortar is to be used in the construction of the central part of the dam and of the center wall and overflow.

The stones used therein must be sound and durable; they must have roughly rectangular forms, and all irregular projections and feather edges must be hammered off. Their beds, especially, must be good for materials of that class, and present such even surfaces that, when lowering a stone on the level surface prepared to receive it, there can be no doubt that the mortar will fill all spaces. After the bed joints are thus secured, a moderate quantity of spalls can be used in the preparation of suitable surfaces for receiving other stones. All other joints must be equally well filled with mortar.

The quality of the beds is to regulate, to a large extent, the size of the stones used, as the difficulty of forming a good bed joint increases with the size of the stones.

Various sizes must be used, and regular coursing must be avoided, in order to obtain vertical as well as horizontal bonding.

The sizes of the stones used will vary also with the character of the quarries, but, especially in the places where the thickness of masonry is great, a considerable proportion of large stones is to be used. If the size and character of the stones, in the opinion of the engineer, shall admit of it, the joints (except the beds), instead of being filled with mortar, may, at his request or on his approval, be filled with concrete made as hereinbefore specified, with the exception that the component materials be mixed in the proportion of one part of cement to three parts of small stone or gravel of such size as the engineer shall direct, and thoroughly rammed, care being taken to use a moderate amount of water only which must be brought to the surface by ramming, such filling of joints with concrete to leave no vacancies and to be thoroughly made. If concrete is so used, the spaces left between the stones should not be less than six inches, in order that proper ramming can be obtained.

No extra compensation shall be paid to the contractor for the use of such concrete, the cost of which is to be included in the price herein stipulated for the masonry in connection with which it is used.

The exposed faces of the main wing wall, of road culverts,

of some of the walls and of any other rubble work that the engineer may designate, are to be made of broken ashlar with joints not exceeding one-half inch in thickness; the stones not to be less than 24 inches deep from the face, and to present frequent headers. This face work to be equal in quality and appearance to the face of the breast wall in front of the new gate house at Croton dam (section 1), and to be well pointed with Portland cement. This face work is to be paid for by the square foot of the superficial area for which it is ordered, in addition to the price paid per cubic yard of rubble stone masonry.

Block stone masonry is to be composed mainly of large blocks and is to be used for the steps of the overfall or for other steps, or whenever and wherever ordered by the engineer. It is to be laid in Portland cement mortar, well pointed, or may be ordered laid dry at the price stipulated in clause O, item (*o*).

This stone, which is to receive the shock of water and ice, is to be especially sound, hard and compact, and of a durable character; it is to be prepared to the dimensions given so that no joint will in any place be more than one inch wide. The outside arrises must be pitched to a true line.

The outer faces of the masonry dam and of its gate chambers, of the overflow (except steps), and of any other piece of masonry that may be designated, are to be made of range stones, as shown on the plans, the stone to be of unobjectionable quality, sound and durable, free from all seams, discoloration and other defects, and of such kind as shall be approved by the engineer.

All beds, builds and joints are to be cut true to a depth of not more than 4 inches, and not less than 3 inches from the faces to surfaces allowing of one-half inch joints at most; the joints for the remaining part of the stones not to exceed two inches in thickness at any point.

All cut arrises to be true, well defined and sharp.

Where this class of masonry joins with granite dimension stone masonry the courses must correspond, and the joining with arches and other dimension stone masonry must be accurate and workmanlike.

Each course to be composed of two stretchers and one header alternately, the stretchers not to be less than 3 feet long nor more than 7 feet long, and the headers of each successive course to alternate approximately in vertical position.

The rise of the courses may vary from bottom to top from 30 inches to 15 inches in approximate vertical progression, and the width of bed of the stretchers is not to be at any point less

than 28 inches. The headers are not to be less than 4 feet in length.

This class of masonry, for the faces of the dam and gate chamber, including the headers, is to be estimated at 30 inches thick throughout. At other places that may be designed by the engineer, the size of the stones is to be established by him, and the facing stone masonry is to be estimated according to the lines ordered or shown on the plans. In no case are the tails of the headers to be estimated.

The work to be equal in quality and appearance to the facing stone masonry work built by the aqueduct commissioners for their masonry dam across the east branch of the Croton river near Brewster.

All copings that may be ordered and the heads of the arches of the highway culverts, will be classed as facing stone masonry.

The price herein stipulated for facing stone masonry is to cover the cost of pointing, of cutting chisel drafts at all corners of the gate-house dam and other corners, and of preparing the rock faces; but if any six-cut or rough-pointed work is ordered in connection with this class of masonry it shall be paid for at the prices therein stipulated for such work.

The face bond must not show less than 12 inches lap, unless otherwise permitted.

The pointing of the faces to be thoroughly made with pure Portland cement after the whole structure is completed; unless otherwise permitted, every joint to be raked out therefor to a depth of at least two inches, and, if the engineer is satisfied that the pointing at any place is not properly made, it must be taken out and made over again.

Granite dimension stone masonry must be made of first-class granite of uniform color, free from all seams, discoloration and other defects, and satisfactory to the chief engineer.

It is to be used for the gate openings in the gate chamber, for the coping of the dam, for the gate-house superstructures and for the crest and first step of the overflow, and at any other place that may be designated by the engineer.

The stones shall be cut to exact dimensions, and all angles and arrises shall be true, well defined and sharp.

All beds, builds and joints are to be dressed, for the full depth of the stone, to surfaces, allowing of one-quarter (¼) inch joint at most. No plug hole of more than 6 inches across or nearer than 3 inches from an arris is to be allowed, and in no case must the aggregate area of the plug-hole in any one joint exceed one-quarter of its whole area.

The stone shall be laid with one-quarter (¼) inch joints,

and all face joints shall be pointed with mortar made of clear Portland cement, applied before its first setting. All joints to be raked out to a depth of two inches before pointing.

The pointing of all masonry, including the faces of the main body of the dam and of the center walls which are below the ground, is to be done thoroughly with Portland cement mortar, mixed clear where used for all exposed faces of brick and cut stone masonry of all kinds (including the rubble facing); and mixed for other work in such proportion as the engineer shall determine. The cost of all pointing is to be included in the price stipulated for the masonry to which it is applied.

The exposed faces of the cut stone are to be finished in various ways, in accordance with the various positions in which they are placed. They shall be either left with a rock or quarry face, rough-pointed, or fine hammered (six-cut work).

The various classes of face dressing must be equal in quality and appearance to those on the sample in the office of the chief engineer.

In rock face work the arrises of the stones inclosing the rock face must be pitched to true lines; the face projections to be bold, and from 3 to 5 inches beyond the arrises. The angles of all walls on structures having rock faces are to be defined by a chisel draft not less than 1½ inches wide on each face.

In rough-pointed work, the stones shall at all points be full to the true plane of the face, and at no point shall project beyond more than ¼ inch, the arrises to be sharp and well defined. Each stone to have its arrises well defined by a chisel draft, which is included in the price for rough-pointed dressing.

In fine hammered work the face of the stones must be brought to a true plane and fine dressed, with a hammer having six blades to the inch.

In measuring cut stone masonry, when the stones are not rectangular, the dimensions taken for each stone will be those of a rectangular, cubical form which will just inclose the neat lines of the same. The price herein stipulated for granite dimension stone masonry is to cover the cost of preparing the rock faces, of making the chisel drafts, and of preparing all holes and recesses and grooves.

No payment will be made for cutting grooves and recesses other than the price paid for the dressing of their surfaces, which are to be fine hammered.

For rough-pointed and fine-hammered (six-cut) dressing, a price per square foot of dressing will be paid in addition to the price per cubic yard of masonry, viz.:

For rough-pointed dressing, the price stiplated in clause O, item (*t*), and for fine-hammered (six-cut) dressing, the price stipulated in clause O, item (*s*).

The exposed parts of the cut stone are generally to be prepared with rock face.

The inside surfaces and copings are generally to be rough-pointed.

All the gateways, grooves, sills, floors, and all other surfaces designated by the engineer are to be fine-hammered. A. F.

**134. Specifications for First-class Bridge Masonry.** The following specification for first-class bridge masonry represents the current practice of one of the leading American engineers:

The face stones shall be laid in regular courses. Copings shall be cut twenty-seven (27) inches thick. Belting courses shall be cut twenty and one-half (20½) inches thick. Starling copings and footings shall be cut thirty (30) inches thick. No course shall be of less thickness than the belting courses; no course shall exceed thirty-six (36) inches in thickness and no course except the coping and the course immediately over the footings shall be thicker than the course beneath.

Face stones shall be of drab-colored stone from the quarries near Bedford, Indiana, or other stone of as good quality acceptable to the engineer. Blue stone from the Bedford or other Oolitic limestone quarries will not be accepted. The up-stream cut-water stone in every course below El. 339 shall be of granite, and also the bridge-seat stones in the copings, as shown on the plans. The remaining coping-stones and the starling copings shall be of limestone of the same quality as the face stones.

The entire masonry shall be built according to detail plans furnished by the engineer.

The stones of each class shall be strong, compact, of uniform quality and appearance, and free from any defects which in the judgment of the engineer might impair its strength or durability.

All stones shall lie on their natural beds in the piers.

Each bed of every stone shall measure at least thirty-six (36) inches in each direction, except that where the thickness of the course is less than twenty-four (24) inches the bed need not exceed one and one-half (1½) times the thickness of the stone.

The bottom bed shall always be the full size of stone, and no stone shall have an overhanging top bed.

Joints shall be broken at least fifteen (15) inches on the face.

Stretchers shall not be less than four (4) nor more than seven (7) feet long, and stretchers of the same width shall not

be placed together vertically; but this shall not be applied to stretchers where headers come centrally between stretchers.

Headers shall be at least five (5) feet long wherever the thickness of the pier permits. They shall be at least three-quarters (¾) their full width for the whole length. There shall be generally four (4) headers in each side of every course between shoulders and never less than three (3) and a like proportion in the curved ends.

The face lines of each course shall be true, and the rise as fixed by the face lines shall not vary anywhere more than one-fourth (¼) inch from the true rise of the course.

The upper and lower beds shall be truly parallel planes and cut to conform to the requirements for the face lines. Depressions of more than one-half (½) inch below the plane of the beds shall not exceed one-tenth (1-10) of the area of the bed in limestone, or one-eighth (⅛) of the area of the bed in granite. There shall be no depressions of more than two (2) inches below the plane of the beds.

Joints shall be cut at right angles to the face and beds of the stone unless otherwise shown on special plans. The cutting for at least twelve (12) inches back from the face shall be the same as that required for the beds.

The vertical joints of face stones shall not average more than one-half (½) inch and shall not exceed three-fourths (¾) inch.

The curved faces of the up-stream cut-water of all piers except Pier I shall be fine-pointed, with no projections exceeding one-half (½) inch.

The copings, including those over the pointed starlings, shall have all exposed surfaces, including the projecting portion of the lower bed, bush-hammered with true lines and surfaces.

A four (4) inch draft line shall be cut on all vertical angles and around the lower edge of the face of the belting course. The projecting portion of the lower bed of the belting course shall be bush-hammered.

All other portions of the piers shall have a rough quarry face with no projections exceeding three (3) inches, the quarry face to average at least one and one-half (1½) inches from the pitch lines of the joints and never to run back from such pitch lines.

The copings shall be cut with close joints throughout the whole course, according to special plans.

No grab holes shall be made on the face of the copings or on the pointed work of the cut-water.

All stones must be carefully cleaned and wet before setting, and no mortar beds shall be laid until the course below has been cleaned and wet.

Every stone shall be laid in a full bed of mortar and settled to a proper bearing, no levelers being allowed.

The vertical joints between stones shall be filled with soft mortar worked in with a trowel and a long thin blade until the joints are completely filled.

The joints, both horizontal and vertical, shall be cleaned out to a depth of one and one-half (1½) inches and pointed in mild weather, the mortar to be driven in hard with a calking iron and the surface finished with a rounded tool.

When masonry is laid in freezing weather such precautions shall be taken to prevent the freezing of mortar before setting as the engineer may direct.

The stones of the curved up-stream starlings of Piers II, III, IV, V and VI shall be doweled into those of the course below with one and one-eighth (1⅛) inch steel dowels extending six (6) inches into each course, these dowels to be placed about ten (10) inches back from the face and seven (7) inches on each side of each joint. The stones of the upper course shall be drilled through before setting, after which the holes shall be extended six (6) inches into the course beneath and cleaned out; a small quantity of mortar shall then be put into the hole, the dowel dropped in and pushed down and the hole filled with mortar and well rammed. The stones in the up-stream end of the buttress of Pier VI and those in the west face of the same for a distance of twenty (20) feet from the down-stream end shall be doweled in the same manner.

The joints of the three courses below the coping shall be cramped with cramps of one (1) inch round steel sixteen inches (16) long, the ends put four (4) inches into each stone.

The backing, except for three courses below the coping shall be of concrete of the proportions of one (1) volume of cement to two and one-half (2½) volumes of sand and five (5) volumes of broken stone.

In the three courses immediately under the coping the backing shall be of limestone of the same quality used for face stone, cut to the same thickness, and the beds cut in the same manner. The spaces not occupied by the large stones shall not be more than one-sixth (1-6) of the area of the course inside of the face stones. These spaces when large enough to permit shall be filled with concrete similar to that used for backing in the courses below. Joints too small to be filled with concrete shall be filled with mortar of the same composition as used for setting face stone. The contractor shall submit to the engineer for approval course plans showing the dimensions of every large backing stone in these courses. In preparing these plans special attention shall be given to the bonding of the stones

under the bridge seat so that the superstructure load may be well distributed over the top surface of the concrete backing.

The cement will be furnished by the bridge company, but the contractor will be held responsible for all waste or injury after it is delivered to him from the company's warehouse.

Sand for mortar or concrete shall be clean, sharp, coarse river sand, or other sand of equal quality in the judgment of the engineer.

Broken stone shall be of hard, sound, clean limestone. It shall be broken by machine and screened in a rotary screen which shall remove all dust and fragments which will pass through holes three-eights (3/8) inch in diameter and all pieces exceeding one and one-half (1 1/2) inches in diameter.

In proportioning materials for mortar and concrete, one (1) volume of cement shall be taken to mean three hundred and eighty (380) pounds net; one (1) volume of sand or broken stone shall be taken to mean three and one-half (3 1/2) cubic feet packed or shaken down. Measurements of sand and broken stone shall be made in barrels or boxes. Measurements in wheelbarrows will not be permitted.

In preparing mortar the specified amounts of cement and sand shall first be mixed dry to a uniform color. The water shall then be added in such a manner as not to cause any washing of the cement, and the mixing proceeded with until the mortar is thoroughly mixed and uniform in appearance.

Wherever possible concrete shall be mixed with a machine approved by the engineer. Preference will be given to a machine which will mix concrete in batches, the cement, sand and broken stone, measured as specified in paragraph —, placed in the machine and mixed dry, the proper amount of water then added and the mixing completed.

When it is impracticable to mix concrete by a machine, it may be made by hand with the special permission of the engineer. The mixing shall be done on a platform of boards or plank securely fastened together. The mortar shall first be made as above specified. The broken stone, previously wetted, shall then be added and the mortar and stone turned over with shovels until the mortar is uniformly distributed through the mass and every stone is coated with mortar.

Concrete shall be deposited in the work in such a manner as not to cause the partial separation of the mortar and stone. It shall be spread in horizontal layers from six (6) to twelve (12) inches in thickness and thoroughly rammed. The rammers shall weigh at least twenty (20) pounds; the end area shall not exceed twenty (20) square inches. The consistency of the concrete shall be as required by the engineer from time

to time, but will generally be such that the concrete will quake under hard ramming.

No mortar or concrete shall be used after it has begun to set; when setting commences the material thus injured shall be immediately wasted. If in the opinion of the engineer the contractor fails to take due precaution against such injury, he will charge to the contractor, and deduct from the estimates the value of the cement in the wasted material.

G. S. M.

## SPECIFICATIONS FOR STREET PAVEMENTS AND MATERIALS.

**135. Specifications for Paving Brick Tests.** The essential properties of a good paving brick are: (*a*) Strength to resist cross breaking; (*b*) strength to resist crushing; (*c*) toughness or strength to resist shocks and blows; (*d*) it must be comparatively non-absorbent. Any brick which possesses these qualities in a high degree will also resist abrasion or wear satisfactorily.

After some twenty years experience in the testing and use of paving bricks, it has been decided by the American Brick Manufacturers' Association, and by the committees of expert engineers which have considered these questions:

*First,* that the various kinds of strength enumerated above under (*a*), (*b*), and (*c*) can all be satisfactorily shown by the rattler test, as described below.

*Second,* That while the absorption test is useful for determining the thoroughness of burning of a given clay, it cannot be used as a fixed criterion of rejection as between bricks burned from different clays without doing injustice to some of them, since a harmless percentage of absorption with one clay would be a dangerous percentage with another.

The following standard rattler test of paving brick has been adopted by the American Brick Manufacturers' Association, in conjunction with an advisory board of engineers (of which the author was a member), and this specification is not likely to be materially changed. It is the final result of an elaborate

series of investigations, extending over several years, and with various types of apparatus:

THE RATTLER TEST.

*Dimensions of the Machine.*—The standard machine shall be 28 inches in diameter and 20 inches in length, measured inside the rattling chamber.

Other machines may be used, varying in diameter between 26 and 30 inches, and in length from 18 to 24 inches, but if this is done, a record of it must be attached to the official report. Long rattlers must be cut up into sections of suitable length by the insertion of an iron diaphragm at the proper point.

*Construction of the Machine.*—The barrel may be driven by trunnions at one or both ends, or by rollers underneath, but in no case shall a shaft pass through the rattler chamber. The cross-section of the barrel shall be a regular polygon, having fourteen sides. The heads shall be composed of gray cast iron, not chilled nor case-hardened. The staves shall preferably be composed of steel plates, as cast iron peans and ultimately breaks under the wearing action on the inside. There shall be a space of one-fourth of an inch between the staves for the escape of the dust and small pieces of waste.

Other machines may be used having from twelve to sixteen staves, with openings from one-eighth to three-eights of an inch between staves, but if this is done a record of it must be attached to the official report of the test.

*Composition of the Charge.*—All tests must be executed on charges containing but one make of paving material at a time. The charge shall be composed of the brick to be tested and iron abrasive material. The brick charge shall consist of that number of whole bricks or blocks whose combined volume most nearly amounts to 1,000 cubic inches, or 8 per cent. of the cubic contents of the rattling chamber. (Nine, ten or eleven are the number required for the ordinary sizes on the market.) The abrasive charge shall consist of 300 pounds of shot made of ordinary machinery cast iron. This shot shall be of two sizes, as described below, and the shot charge shall be composed of one-fourth (75 pounds) of the larger size and three-fourth (225 pounds) of the smaller size.

*Size of the Shot.*—The larger size shall weigh about seven and one-half pounds and be about two and one-half inches square and four and one-half inches long, with slightly rounded edges. The smaller size shall be one and one-half inch cubes, weighing about seven-eighths of a pound each, with square corners and edges. The individual shot shall be replaced by

new ones when they have lost one-tenth of their original weight.

*Revolutions of the Charge.*—The number of revolutions of the standard test shall be 1,800, and the speed of rotation shall not fall below 28 nor exceed 30 per minute. The belt power shall be sufficient to rotate the rattler at the same speed whether charged or empty.

*Condition of the Charge.*—The bricks composing a charge shall be thoroughly dried before making the test.

*The Calculation of the Results.*—The loss shall be calculated in percentages of the weight of the dry brick composing the charge, and no results shall be considered as official unless it is the average of two distinct and complete tests, made on separate charges of brick.

**136. Specifications for Brick Paving.** The specifications in this and the following articles for various kinds of wearing surfaces of street pavements are taken from the standard specifications used in the city of St. Louis. In these specifications all the general clauses and also all detailed description of the grading, curb, gutter, and foundation will be omitted, since it is the intention to include in them only that portion of the specification describing the wearing surface.

In this specification for brick pavement, after describing the curbing, preparation of the roadbed, which involves a thorough rolling with a steel roller, weighing not less than ten tons, or three hundred pounds per lineal inch of roller; also the concrete foundation of six inches in depth, the following specification is given for

WEARING SURFACE.

Upon the foundation of concrete shall be laid a bed of coarse, screened sand, about two inches in thickness when compacted, to serve as a bed for the bricks. Upon this base of sand a pavement of the best quality of vitrified paving brick shall be laid. Great care must be taken to have the surface of this sand layer exactly parallel to the desired street surface after completion. To accomplish this a wooden screed must be used whose lower side is cut out to the proper curve by computing a sufficient number of ordinates. The screed will rest on one end on top of the curb and will reach to the center of the street or railroad track, where it will rest on a carefully adjusted piece of scantling or on the top of rail respectively. It shall then be properly weighted and drawn along slowly; an almost

perfect sand grade will thus be obtained. No hand luting will be permitted except where the use of screed is impossible. The bricks shall not be less than eight inches nor more than nine inches long, not less than two and one-half inches nor more than three inches wide, not less than four inches nor more than four and one-half inches deep, with rounded edges with a radius of three-eighths of an inch. Said brick shall be of the kind known as "repressed" brick, and shall be repressed to produce a mass free from internal flaws, cracks or laminations.

The bricks shall be free from lime or other impurities that will injuriously affect them when immersed in water, uniform in size and quality, and thoroughly burned and annealed.

All bricks so distorted in burning, or with such prominent kiln marks as to produce an uneven pavement, shall be rejected.

Each bidder shall submit one hundred bricks, which shall be subjected to such physical tests as may, in the opinion of the street commissioner, be necessary to determine their quality and suitability for the work.

To secure uniformity in bricks of approved manufacture, delivered for use, the following tests shall be made:

1. They shall show a modulus of rupture in cross-breaking of not less than two thousand pounds per square inch.

2. Specimen bricks shall be placed in the machine known as a "rattler" twenty-eight inches in diameter, making thirty revolutions per minute. The number of revolutions for a standard test shall be eighteen hundred, and if the loss of weight by abrasion or impact during such test shall exceed twenty-five per cent. of the original weight of the bricks, then the bricks shall be rejected. An official test to be the average of two of the above tests.

3. They shall not absorb more than two per cent. of their own weight of water after being immersed for forty-eight hours: this test to be made after bricks have been broken and passed through the rattler.

No bid contemplating the use of rejected brick shall be entertained.

Samples may be submitted by manufacturers, in which case the bidder proposing to use brick of such manufacture will not be required to submit samples. The quality of brick furnished must conform to the samples presented by the manufacturers and kept in the office of the street commissioner. The street commissioner reserves the right to reject any and all bricks, which, in his opinion, do not conform to the above specifications. Any brick may have a proper shrinkage, but shall not differ materially in size from the accepted samples of the same make, nor shall they differ greatly in color from the natural color of the well-burned brick of its class and manufacture.

No bats or broken bricks shall be used, except at the curbs or gutter as the case may be, where nothing less than a half brick shall be used to break joints. The bricks to be laid in straight lines and all joints broken by a lap of at least two inches, to be set on edge on the sand as closely and compactly as possible and at right angles with the line of the curb or gutter, as the case may be, except at street intersections, where they are to be laid as the street commissioner may direct.

The pavement to be surfaced up by a thorough rolling with a steam roller weighing not less than three nor more than six tons, and when completed to conform to the true grade and cross-sections of the roadway. Wherever a roller cannot be used, the pavement to be thoroughly rammed two or three times with a paver's rammer weighing not less than seventy-five pounds.

An expansion joint one inch in width shall be placed on each side of the roadway against the curb or outer edge of gutter, as the case may be. This joint, about four inches in depth, shall be filled with pitch, heated to a temperature of three hundred degrees, Fahrenheit, to within one-half inch of surface of pavement; the remaining one-half inch to receive a dressing of clean, coarse sand.

All joints in the pavement shall be completely filled with Portland cement grout.

The grout shall be mixed in portable boxes in the proportion of one part cement to one part sand. Not more than one ordinary water bucket full of cement with the same amount of fine sand shall be mixed at a time. The cement and sand to be thoroughly mixed dry until no streaks appear in the mixture, then sufficient water to be added to make the grout of proper fluidity, when properly stirred. The grout shall be transferred to the pavement in scoop shovels and rapidly swept into the joints by steel brooms. During this procedure the grout remaining in the box must be constantly stirred in order to prevent a separation of the sand from the cement. After the grouting of the pavement has been completed the newly finished work must be kept from traffic by putting up substantial blockades and if deemed necessary by watchmen stationed to protect the barricades. This blockade must be kept up for at least seven days after the grout is applied.

The surface of the pavement, when completed, shall be covered with one-half inch of clean, coarse sand of approved quality, which, with all dirt, shall be removed from the pavement and sewer inlets by or at the expense of the contractor at such time before the final acceptance of the work as the street commissioner may direct. St. L.

Following the above specification is a "maintenance clause," similar to that given in the following article, providing for the maintenance of the pavement in good repair for a period of nine years.[1] The contract price provided also for an annual sum to be paid for maintenance, and the bond given by the contractor covered the maintenance, as well as the original construction.

The tests to which the brick are submitted under this specification are the same as those given in Art. 133.

137. **Specification for Asphaltum Pavement.** After describing the preparation of the roadbed, curbing, concrete foundation, having a depth of five inches, etc., the following specifications of the asphaltum body and wearing surface are employed:

BINDER.

The second or binder course will consist of a fine bituminous concrete composed of clean broken stone, slag or gravel, not exceeding one and one-half (1½) inches in their largest dimensions, thoroughly screened, and asphaltic cement made from lake asphalt, as below described. The stone, slag or gravel, will be heated by passing through revolving heaters and thoroughly mixed by machinery with the asphaltic cement in the proportion of not less than fifteen (15) gallons of the asphaltic cement to one (1) cubic yard of stone, slag or gravel. The mixture will be so made that the resulting binder has life and gloss without an excess of cement. Should it appear dull from over-heating or lack of cement it will be rejected. This binder will be hauled to the work and spread on the base with hot iron rakes, and immediately rammed and rolled with hand and steam rollers, while in a hot and plastic condition, until it has a thickness of one and one-half (1½) inches. The upper surface will be made exactly parallel with surface of the pavement to be laid.

WEARING SURFACE.

Upon this binder course thus prepared shall be laid a wearing surface or pavement proper, the basis of which shall be composed of lake asphalt unmixed with any of the products of coal tar, of a nature and quality proved to be durable and proper by having been in successful use in roadway pavements

[1] This clause was declared illegal under the former charter, but is now (1902) enforced under a new charter amendment which provides for a "guarantee" and for keeping the pavement in repair for a term of years.

in one or more cities of the United States for a period of at least two years and in an amount greater than five thousand square yards in each of said cities.

The wearing surface shall be composed of—

1st. Refined lake asphaltum.

2d. Heavy petroleum oil.

3d. Clean sharp sand.

4th. Fine powder of carbonate of lime.

Refined asphalt shall be smooth and free from lumps of unmelted pitch or organic matter not bituminous. It shall not at any time reach a temperature over 375 degrees Fahrenheit. The asphaltic cement shall be prepared from such refined asphalt as may be approved by the street commissioner, and suitable heavy petroleum oil or other approved solvent.

The heavy petroleum oil, which may be the residuum by distillation of the petroleum oils as found in the market, generally contains water, light oils, coke, and a gummy substance soluble in water. This petroleum oil is freed from all impurities and brought to a specific gravity of from 18 degrees to 22 degrees Beaume, and a fire test of 250 degrees Fahrenheit.

To the melted asphalt, at a temperature of not over 325 degrees Fahrenheit, the oil, after having been heated to at least 150 degrees Fahrenheit, is to be added in suitable proportions to produce an asphalt cement. To accomplish this, from 15 to 21 pounds of oil per 100 of refined asphalt will be required. As soon as the oil has begun to be added, suitable agitation, by means of an air blast or other acceptable appliances, will commence and be continued till a homogeneous cement is produced. The appliances for agitation shall be such as to accomplish this in at least ten hours, during which the temperature shall be kept at from 290 degrees to 325 Fahrenheit, and no higher. If the cement then appears homogeneous and free from lumps and from inequalities, as shown by samples from different parts of the still, it may be used. Should it not prove homogeneous, such deficiencies as may exist shall be corrected by the addition of hot oil or melted asphalt, in the necessary proportion.

They shall be mixed in the following proportions by weight:

| | |
|---|---|
| Pure asphalt | 100 parts |
| Heavy petroleum oil | 15 to 20 parts |

The asphaltic cement being made in the manner above described, the pavement mixture shall be formed of the following materials, and in proportion stated:

| | | |
|---|---|---|
| Asphaltic cement | from 12 to | 15 |
| Sand | from 83 to | 70 |
| Pulverized carbonate of lime | from 5 to | 15 |
| | 100 | 100 |

Limestone dust shall be an impalpable powder of carbonate of lime, the whole of which will pass a 30-mesh screen, and at least 75 per cent. pass a 100-mesh screen.

The sand and asphaltic cement are heated separately to about three hundred degrees Fahrenheit. The pulverized carbonate of lime, while cold, is mixed with the hot sand in the required proportions, and is then mixed with the asphaltic cement at the required temperature, and in the proper proportion, in a suitable apparatus, which will effect a perfect mixture.

The pavement mixture, prepared in the manner thus indicated, shall be laid on the foundation. It shall then be carefully spread, by means of hot iron rakes, in such manner as to give a uniform and regular grade, and to such depth that after having received its ultimate compression, it shall have a thickness of two inches. The surface shall then be compressed by rollers; after which a small amount of hydraulic cement shall be swept over it, and it shall then be thoroughly compressed by a steam roller, weighing not less than ten (10) tons, in order to get a thoroughly compressed wearing surface, the rolling being continued as long as it makes an impression on the surface.

The powdered carbonate of lime shall be of such degree of fineness that 5 to 15 per centum by weight of the entire mixture for the pavement shall be an impalpable powder of limestone, and the whole of it shall pass a No. 26 screen. The sand shall be of such size that none of it shall pass a No. 80 screen, and the whole of it pass a No. 10 screen.

In order to make the gutters, which are consolidated but little by traffic, entirely impervious to water, a width of twelve inches next to curb shall be coated with hot, pure asphalt and smoothed with hot smoothing irons, in order to saturate the pavement to a certain depth with an excess of asphalt.

## TOOLS AND SAMPLES OF MATERIALS.

The contractor shall furnish and have on the line of work at all times, a complete and sufficient plant of tools, rollers, carts, etc., as may be determined by the street commissioner, to carry on the work in an expeditious and workmanlike manner, also furnish samples of the crude lake asphalt to be used in the work, properly labeled, also samples of the wearing surfaces as prepared for use, and the statement of the amount of each material used in making up the pavement mixtures, when called for by the street commissioner.

In order that the asphalt may be fully tested, each bidder must deposit with the street commissioner, at least three days

before making his bid, samples of materials he intends to use, together with certificates and statements as follows:

1. A specimen of the crude asphaltum not less than five (5) pounds in weight with a certificate stating the place from whence the asphaltum was taken.

2. A specimen of the asphaltic cement not less than five (5) pounds in weight with a statement of its composition, and also a statement of the composition of the proposed wearing surface.

3. A sample of the pavement surface showing the asphalt after two years' actual use in a street, said sample to be not less than one foot square and to be accompanied by a certificate from the proper city official showing the time during which said pavement has been in use on the street on which it was laid, and the certificate shall further show that the pavement from which the sample is taken, or similar pavement, has been in successful use on one or more roadways in said city for a period longer than two years, and in an amount greater than five thousand (5,000) square yards.

4. A statement of the location and the capacity in square yards per day of the works or factory where the paving material is to be prepared.

Specimens must be furnished to the street department as often as may be required during the progress of the work.

### MAINTENANCE.

The said ———, party of the first part, expressly guarantees to maintain at grade and surface in good order the aforesaid work of reconstruction throughout and at the end of the full period of nine years, commencing one year after the said work of reconstruction is completed and accepted, and binds himself, his heirs and assigns to make all repairs which may from any imperfection in said work or materials or from any rotting, crumbling or disintegration of the materials, become necessary within that time; and the party of the first part shall, whenever notified by the street commissioner that repairs are required, at once make such repairs at his own expense, and if they are not made within the proper time, the street commissioner shall have power to cause such repairs to be made, and the cost thereof shall be paid out of the fund provided for the payment of contracts for street maintenance, and the amount shall be deducted from any money then due under the contract, or which may thereafter become due. At the end of the nine-year period the street commissioner must determine whether or not the street is in good order at grade and surface, and the principal and his sureties under this contract shall not be discharged from liability on their maintenance bond hereunder

until the street commissioner shall so determine and certify thereto in writing to the principal under this contract. And it is further expressly agreed, that if at any time during the term for which the contract for the maintenance of the above street is in force, the pavement of said street, or any part thereof, has deteriorated to such an extent as to require, in the opinion of the board of public improvements, reconstruction, the street commissioner shall, with the approval of the board of public improvements and of the mayor, notify the contractor that reconstruction is necessary, and the contractor shall, within three months after receiving such notice, reconstruct the whole or such part of the pavement with the same kind of material as heretofore applied, or with some other material approved by the board of public improvements. And if the contractor fails to reconstruct the street within three months after having been notified, the board of public improvements may, with the approval of the mayor, cancel the contract and relet the work of reconstructing the pavement, and that the cost of such reconstruction shall be paid by the city and the amount collected by suit from the contractor or his sureties, not to exceed fifteen dollars per square of pavement, included in the contract.

And it is further agreed that whenever any repairs of the street are made necessary from the construction of sewers, the laying of pipes or telegraph wires, or from any other disturbance of the pavement by parties acting under permits issued by the city, the contractor shall on notification from the street commissioner, immediately make all necessary repairs in conformity with the specifications for this class of work. The cost of all such repairs, exclusive of trenching and back filling, which shall be done by the parties who hold the permits, and in the same manner as now required by existing ordinances, shall be paid for at the full contract price for a superficial square of new pavement out of the fund set apart for the payment of contracts for the maintenance of streets, and the amount shall be certified by the street commissioner to the auditor, who shall reimburse, by transfer, the aforesaid fund from the funds of the proper department, if the repairs were made necessary by the construction of any public improvement; and out of the funds to be deposited by persons obtaining permits for opening streets before such permits are granted, if the repairs are made necessary by work done under such permits. And it is agreed that the contractor shall have the right to make all repairs which become necessary by the construction of any public improvement or work done by private parties under permits given by the city. St. L.

**138. Specification for Asphalt Pavement.** The following specification for asphalt pavement was prepared in 1892 for the department of public parks, of New York city (and incorporated by Mr. A. P. Boller), for such a pavement upon the new Harlem river bridge at One Hundred and Fifty-fifth street, New York. It probably embodies the latest and most approved methods of making such a pavement, and so far as it is applicable to ordinary street pavements, it might be followed with advantage:

The subsurface must then be brought to a uniform grade and cross-section not to exceed a crown of three inches in width of roadway by filling all depressions with a fine bituminous concrete or binder, to be composed of clean, broken stone not exceeding one inch in their largest dimensions, thoroughly screened, and coal tar residuum, commonly known as No. 4 paving composition.

If required by the department of public parks, clean, sharp sand may replace a portion of the broken stone.

The stone or stone and sand must be heated by passing through revolving heaters, and thoroughly mixed by machinery with the paving composition in the proportion of one (1) gallon of paving composition to one (1) cubic foot of stone.

This binder must be hauled to the work and spread with hot iron rakes in all holes or inequalities and depressions below the true grade of the pavement, to such thickness that after being thoroughly compacted by tamping and hand rolling the surface shall have a uniform grade and cross-section, and the thickness of the binder at any point shall be not less than three quarters of an inch.

The upper surface shall be exactly parallel with the surface of the pavement to be laid.

Upon this foundation must be laid the wearing surface or paving proper, the basis of which or paving cement must be pure asphaltum, unmixed with any of the products of coal tar.

The wearing surface must be composed of:—

1. Refined asphaltum.
2. Heavy petroleum oil.
3. Fine sand, containing not more than one per centum of hydro-silicate of alumina.
4. Fine powder of carbonate of lime.

The asphaltum must be specially refined and brought to a uniform standard of purity and gravity of a quality to be approved by the engineer.

The heavy petroleum oil must be freed from all impurities

and brought to a specific gravity of from eighteen to twenty-two degrees Beaume, and a fire test of two hundred and fifty degrees Fahrenheit.

From these two hydro-carbons shall be manufactured an asphaltic cement which shall have a fire test of two hundred and fifty degrees Fahrenheit, and at a temperature of sixty degrees Fahrenheit shall have a specific gravity of 1.19, said cement to be composed of one hundred parts of pure asphalt and from fifteen to twenty parts of heavy petroleum oil.

The asphaltic cement being made in the manner above described, the pavement mixture will be formed of the following materials, and in the proportions stated:

| | |
|---|---|
| Asphaltic cement | from 12 to 15 |
| Sand | from 83 to 70 |
| Pulverized carbonate of lime | from 5 to 15 |

The sand and asphaltic cement are to be heated separately to about three hundred degrees Fahrenheit. The pulverized carbonate of lime, while cold, shall be mixed with the hot sand in the required proportions, and then mixed with the asphaltic cement at the required temperature, and in the proper proportion, in a suitable apparatus, which will effect a perfect mixture.

The pavement mixture prepared in the manner thus indicated must be brought to the ground in carts at a temperature of about two hundred and fifty degrees Fahrenheit, and if the temperature of the air is less than fifty degrees, iron carts, with heating apparatus, must be used in order to maintain the proper temperature of the mixture; it shall then be carefully spread by means of hot iron rakes. in such manner as to give a uniform and regular grade, and to such depth that after having received its ultimate compression, it will have a thickness of two inches at crown of roadway, tapering off, if required, to about one inch at gutters. The surface shall then be compressed by hand rollers, after which a small amount of hydraulic cement shall be swept over it, and it shall then be thoroughly compressed by a steam roller weighing not less than two hundred and fifty pounds to the inch run; the rolling to be continued for not less than five hours for every one thousand yards of surface.

The powdered carbonate of lime must be of such degree of fineness that five to fifteen per centum by weight of the entire mixture for the pavement shall be of an impalpable powder of limestone, and the whole of it shall pass a No. 26 screen. The sand must be of such size that none of it shall pass a No. 80 screen, and the whole of it must pass a No. 10 screen.

In order to make the gutters, which are consolidated but little by traffic, entirely impervious to water, a width of twelve inches next the curb must be coated with hot, pure asphalt

and smoothed with hot smoothing irons in order to saturate the pavement to a certain depth with an excess of asphalt.

If rock asphalt be used, it must be natural bituminous limestone rock: (1) from the Sicilian mines at Ragusa, equal in quality and composition to that mined by the United Limmer & Ver Wohle Rock Asphalte Company, Limited; (2) from the Swiss mines at Val de Travers, equal in quality and composition to that mined by the Neuchatel Rock & Asphalte Company, Limited, or (3) from the French mines at Seyssel, equal in quality and composition to that mined by the Compagnie Generale des Asphaltes de France, and it shall be prepared and laid as follows:

(1) The lumps of rock shall be finely crushed and pulverized, the powder shall then be passed through a fine sieve. Nothing whatever shall be added to or taken from the powder obtained by grinding the bituminous rock. The powder shall contain from nine to twelve per cent. natural bitumen, eighty-eight to ninety-one per cent. pure carbonate of lime, and must be free from quartz, sulphates, iron pyrites, or aluminum. (2) This powder shall be heated in a suitable apparatus to two hundred or two hundred and fifty degrees Fahrenheit, and must be brought to the ground at such temperature in carts made for the purpose, and then carefully spread on the foundation previously prepared, to such depth that, after having received its ultimate compression, it will have a thickness of two inches. (3) It shall be skilfully compressed by heated rammers and rolled until it shall have the required thickness of two inches. (4) The surface to be rendered perfectly even by heated smoothers, and to be rolled with a steam roller weighing not less than two hundred and fifty pounds to the inch run, the rolling to continue for not less than five hours for each one thousand yards of surface. A. P. B.

**139. Specification for Granite Pavement.** The following specification for granite pavement is that used in the city of Milwaukee so far as the granite paving is concerned. These granite blocks are laid upon a concrete foundation six inches thick, and this latter upon a carefully prepared surface which has been thoroughly rolled with a heavy roller. The concrete is made of natural cement one part, sand two parts, and broken stone five parts. On this is spread a sand cushion two inches thick when compacted, on which the granite blocks are laid:

*Granite Block Paving.*—The blocks must consist of a hard granite uniform in grain and texture, without lamination or stratification and free from excess of mica or feldspar. Neither hard basaltic stone that will take a smooth polish under

traffic, nor soft or weather worn stones nor syenite will be accepted. The blocks must be rectangular in form, of not less than three (3) nor more than four and one-half (4½) inches in thickness, nor less than six (6) or more than seven (7) inches in depth, nor less than eight (8) or more than twelve (12) inches in length, and so split and dressed with fair and true surfaces on top, bottom and ends so that when laid close together the end joints will fit close together, and the side joints will not exceed three-fourths (¾) inch in width. The blocks will be imbedded in the sand bed and laid at right angles to the line of the street, except at street and alley intersections, where the same will be laid at an angle of about 45 degrees with the line of the street. The stone will be laid close together with the top surface smoothly conforming to the crown of the street. Each course is to be of uniform width, with each longitudinal joint broken by a lap of not less than two inches. The blocks are to be immediately covered with sufficient, clean, fine, hot, screened gravel to fill the joints, to not more than three and one-half (3½) inches from the top after which the blocks will be tamped with a heavy paver's ram to a firm, unyielding and uniform smooth surface. The joints will then be filled flush with top of pavement with a hot paving cement obtained by direct distillation of coal tar, immediately after which fine, dry, hot gravel will be run into the joints. Not less than three (3) gallons of paving cement shall be used to each square yard of pavement.[1]

**140. Specification for Granitoid Sidewalks.** Sidewalks made after the following specifications are now exclusively used in St. Louis, and have been in use in that city for many years. Where granite can be obtained at a reasonable price, it is thought this composition is more durable and satisfactory for sidewalks than any other material or mixture which has ever been used. The making of these sidewalks has grown to be a very large industry in St. Louis and the price has been gradually reduced because of the great amount of this kind of work done, until in 1895, the total cost of removing old pavement, regrading, laying the foundation and pavement as here described in the most approved manner, and strictly in accordance with this specification is from eighteen to twenty cents per square foot for the "ordinary single flagging."

The sidewalks shall be of three separate and distinct thickness and kinds, and shall be classified as follows: "ORDINARY

[1] This treatment of the joints is especially satisfactory.—AUTHOR.

SINGLE FLAGGING," "EXTRA DOUBLE THICK FLAGGING," and "DRIVEWAY OF ENTRANCE FLAGGING," and shall be laid in the different localities within the above described limits at the discretion of the street commissioner, who shall determine which of the above named kinds shall be laid.

*Preparation of Bed.*—The sidewalks shall be excavated and shaped to the proper depth and grade as directed by the street commissioner, and all the refuse material therefrom shall belong to the contractor and shall be promptly removed from the line of work.

*Ordinary Single Flagging.*—After the shaping is done a foundation of cinders not less than eight (8) inches thick shall be placed upon the subgrade, which shall be well consolidated by ramming to an even surface, and which shall be moistened just before the concrete is placed thereon.

After the sub-foundation has been finished the artificial stone flagging shall be laid in a good workmanlike manner.

The same to consist of two parts: First, a bottom course to be three and one-half (3½) inches in depth. Second, a finishing or wearing course, to be one-half (½) inch in depth.

The bottom course shall be composed of crushed granite and the best Portland cement, equal to the Dyckerhoff brand, and capable of withstanding a tensile strain of 400 pounds to the square inch after having been three hours in air and seven days in water, and shall be mixed in the proportion of one part cement to three parts of crushed granite.

The crushed granite shall consist of irregular, sharp-edged pieces, so broken that each piece will pass through a three-fourths (¾) of an inch ring in all its diameters, and which shall be entirely free from dust or dirt.

The crushed granite and the cement in the above mentioned proportions shall first be mixed dry, then sufficient clean water shall be slowly added by sprinkling, while the material is constantly and carefully stirred and worked up, and said stirring and mixing shall be continued until the whole is thoroughly mixed.

This mass shall be spread upon the sub-foundation and shall be rammed until all the interstices are thoroughly filled with cement.

Particular care must be taken that the bottom course is well rammed and consolidated along the outer edges.

After the bottom course is completed, the finishing or wearing course shall be added. This course to consist of a stiff mortar composed of equal parts of Portland cement and the sharp screenings of the crushed granite, free from loamy or earthy subbstances, and to be laid to a depth of one-half (½) of an inch and to be carefully smoothed to an even surface

which, after the first setting takes place, must not be disturbed by additional rubbing.

When the pavement is completed it must be covered for three days and be kept moist by sprinkling.

*Extra Double Thick Flagging.*—After the grading and shaping is done, a foundation of cinders not less than six (6) inches thick shall be placed upon the subgrade, which shall be well consolidated by ramming to an even surface and which shall be moistened just before the concrete is placed thereon. After the sub-foundation has been finished the artificial stone flagging shall be laid in a good, workmanlike manner.

The same to consist of two parts: First, a bottom course to be five (5) inches in depth. Second, a finishing or wearing course to be one (1) inch in depth.

The bottom course shall be composed of crushed granite and the best Portland cement equal to the Dyckerhoff brand, and capable of withstanding a tensile strain of 400 pounds to the square inch after having been three hours in air and seven days in water, and shall be mixed in the proportion of one part of cement to three parts of crushed granite.

The crushed granite shall consist of irregular, sharp-edged pieces, so broken that each piece will pass through a three-fourth (¾) of an inch ring in all its diameters, and which shall be entirely free from dust or dirt.

The crushed granite and the cement in the above mentioned proportions shall first be mixed dry, then sufficient clean water shall be slowly added by sprinkling, while the material is constantly and carefully stirred and worked up, and said stirring and mixing shall be continued until the whole is thoroughly mixed.

This mass shall be spread upon the sub-foundation and shall be rammed until all the interstices are thoroughly filled with cement.

Particular care must be taken that the bottom course is well rammed and consolidated along the outer edges.

After the bottom course is completed the finishing or wearing course shall be added. This course to consist of a stiff mortar composed of equal parts of Portland cement and the sharp screenings of the crushed granite, free from loamy or earthy substances, and to be laid to a depth of one (1) inch and to be carefully smoothed to an even surface, which, after the first setting takes place, must not be disturbed by additional rubbing.

When the pavement is completed it must be covered for three days and be kept moist by sprinkling.

*Driveway or Entrance Flagging.*—After the grading and shaping is done, a foundation of crushed limestone and hyraulic cement mortar shall be laid to a depth of six (6) inches on the subgrade. The stone used in this concrete shall be broken so as to pass through a two (2) inch ring in its largest dimensions. The stone shall be cleaned from all dust and dirt and thoroughly wetted and then mixed with mortar, the general proportion being: One part of cement, two parts of sand, and five parts of stone. It shall be laid quickly and then rammed until the mortar flushes to the surface. No walking or driving over it shall be permitted when it is setting, and it shall be allowed to set for at least twelve hours, and such additional length of time as may be directed by the street commissioner or by his duly authorized agents, before the pavement is put down.

After the subfoundation has been finished, the artificial stone flagging shall be laid in a good, workmanlike manner. The same to consist of two parts: First, a bottom course to be five (5) inches in depth. Second, a finishing or wearing course to be one (1) inch in depth.

The bottom course shall be composed of crushed granite and the best Portland cement, equal to the Dyckerhoff brand, and capable of withstanding a tensile strain of 400 pounds to the square inch after having been three hours in air and seven days in water, and shall be mixed in the proportion of one part cement and three parts of crushed granite.

The crushed granite shall consist of irregular, sharp-edged pieces, so broken that each piece will pass through a three-fourths (¾) of an inch ring in all its diameters, and which shall be entirely free from dust or dirt.

The crushed granite and the cement in the above mentioned proportions shall first be mixed dry, then sufficient clean water shall be slowly added by sprinkling, while the material is constantly and carefully stirred and worked up, and said stirring and mixing shall be continued until the whole is thoroughly mixed.

This mass shall be spread upon the subfoundation and shall be rammed until all the interstices are thoroughly filled with cement.

Particular care must be taken that the bottom course is well rammed and consolidated along the outer edges.

After the bottom course is completed, the finishing or wearing course shall be added. This course to consist of a stiff mortar composed of equal parts of Portland cement and the sharp screenings of the crushed granite, free from loamy or earthy substances, and to be laid to a depth of one (1) inch

and to be carefully smoothed to an even surface, which, after the first setting takes place, must not be disturbed by additional rubbing.

When the pavement is completed, it must be covered for three days and be kept moist by sprinkling. St. L.

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## SPECIFICATIONS FOR SEWERS.

**141. Specifications for Brick and Tile Sewers.** The following specifications for brick and tile sewers are those used in the city of St. Louis, so far as they relate to the construction proper, except that part relating to the use of cement, concrete, and rubble masonry. As specifications on these subjects are given elsewhere, they are not included here:

*Excavation.*—All excavation shall be done by open cut from the surface, except where tunneling is shown on the plans or is expressly permitted or directed by the sewer commissioner.

Wherever the material is of such a nature as to allow it, the bottom of the excavation up to the greatest horizontal diameter of the sewer shall be made with a template so as to conform to the exact shape of the brickwork. Above this line the cut may, in all ordinary cases, be carried to the surface at such a slope as the contractor may desire, but it will be calculated with a slope of one horizontal to —— —— vertical, whatever may be the actual slope. Should the contractor think it best to keep the sides of the excavation vertical by bracing or otherwise, it is expressly understood that it shall be done at his own cost and risk.

Rock shall be excavated so as to conform as nearly as possible to the lower half of the sewer, and all irregularities shall be filled with masonry or concrete so as to make a smooth bed for the brick work. The amount of the excavation in rock cuts will be calculated with a base at the bottom of the brickwork equal to the greatest horizontal diameter of the sewer, and with side slopes of the same inclinations as in other excavations. All the rock taken from the excavations shall belong to the contractor for his own use.

Wherever the excavation can not be adapted to the shape of the brickwork, it shall be done according to such directions as may be given in each case.

The sides of the excavation shall, whenever it may be neces-

sary, be supported with suitable plank and shoring, but no allowance will be made therefor unless the same is left in by express orders of the sewer commissioner, when it will be paid for at —— dollars per thousand feet, board measure. In all other cases it will be drawn as the work progresses and not paid for by the city.

The contractor shall, at his own cost, keep the trenches free from water during the progress of the work. Excavated material must be so placed as not to interfere with travel on the street or to incommode occupants of adjoining property. Trenches shall not be opened more than 200 feet in advance of the laying of the sewer.

*Back Filling.*—Back filling shall follow close after the construction of the sewer, and in no case be more than 100 feet in the rear.

The filling of the earth around and on top of the sewers shall be done with the utmost care, and in a manner to obtain the greatest compactness and solidity possible. For that purpose the earth shall be laid and rammed in regular layers not more than nine inches thick up to the surface of the street, or thoroughly soaked with water, as may be directed by the sewer commissioner.[1] The macadamizing, if any has been removed, shall be carefully replaced on the top of the said filling; and when paving has been removed it shall be replaced in the same manner as when originally constructed, and the street or alley left in as good condition as it was before. If any new materials are needed for such repairing, they shall be of the best quality, and shall be furnished and put down by the contractor at his own cost.

The gutter paving in front of the adjoining sewer inlets shall be taken up and replaced in proper shape, so as to conduct the storm water into the sewer inlets.

All work of restoring the surface of the streets and alleys shall be done to the satisfaction of the street commissioner, or his duly authorized agents, immediately after the sewer is laid. If not so done within five days after notice, the work may be done by the street commissioner, and the cost thereof shall be paid by the contractor; and in default of payment, the cost may be retained by the city of St. Louis, out of any money that may be due or become due to the contractor under this contract.

*Surplus Earth.*—All surplus earth shall be hauled away promptly to such places, within a distance of 3,000 feet, as the sewer commissioner shall designate, and be spread according

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[1] A better plan is to thoroughly ram the layers in nine-inch courses, and then to *also* thoroughly soak with water every four or five feet whenever water is available.

to his directions; but if no such place is designated, the contractor shall dispose of such surplus at his own risk and expense. No surplus earth shall be deposited on private property, if, within the limit just named, it can be used on the streets or alleys or other public places. But if no such use can be found for it, it may, with the consent of the sewer commissioner, be deposited on private property; but all earth so deposited without the consent of said commissioner, shall be measured, and the amount thereof deducted from the measurement of the excavation.

The price paid for earth and rock excavation shall cover the whole cost of excavating the trenches and refilling the same with earth, restoring the street and hauling away the surplus materials, as well as the whole cost of pumping, bailing, planking, and shoring, excepting such planking as may be left in by express orders as hereinbefore specified.

*Bricks.*—All the bricks used shall be of uniform texture, hard-burned entirely through, free from lime or other impurities, that will affect them in water, and shall have straight edges and square angles. Broken bricks must not be brought on the ground, and such as are broken afterwards in handling shall be used only in making closures, or as shall be otherwise specially directed.

The bricks are to be culled as they are brought on the ground, and all bricks of improper quality thrown out and removed from the ground. The culling to be done at the expense of the contractor, who shall furnish the inspector with men for this and similar purposes, when required.

*Brick Masonry.*—In building brick masonry, none but careful and skillful bricklayers shall be employed.

The bricks shall be clean and thoroughly wet just before being laid, unless otherwise specially directed. Every brick shall be laid with a *push joint;* that is, by placing sufficient mortar on the bed and forcing the brick into it in such a manner as to thoroughly fill every joint, whether on the bottom, side or end of the brick with mortar. The joints shall be made as nearly as possible of uniform thickness, not exceeding three-eighths of an inch, and in the inside of the invert or lower arch, they shall not exceed one-eighth of an inch.

The bricks in each course shall be all stretchers, and to break joints with those in the adjoining courses. The bricks of the inside course shall be laid to a line and to the true cylindrical or other form given for each case. The inside course shall also be made of the smoothest and hardest bricks, carefully selected for this purpose.

The upper arch shall be built on strongly made centers, which shall be drawn with great care, so as not to disturb the

brickwork. The crown of the arch shall be properly keyed with stretchers, and all the joints be well filled with the mortar. The exterior surface of the upper arch shall be covered with a coating of mortar, not less than three-eighths (⅜) of an inch thick.

The mortar joints on the inside of the sewer below the center line shall be carefully struck when laid, and those above be scraped smooth with the brickwork immediately after the centers are drawn, and the mortar scraped off and entirely removed from the sewer, which is to be left perfectly clean throughout.

All unfinished brickwork must be racked back in courses, except when otherwise specially directed or permitted, and when new work is to be joined to it, the surface of the bricks must be cleaned and moistened.

Openings for branch sewers shall be made and junction pieces inserted in the main sewers in such manner and at such places as may be directed. Every junction piece shall be closed with a cover of earthenware, or with bricks and cement.

All brickwork will be measured and paid for by the cubic yard of solid wall.

## TUNNELING.

In tunneling, the excavation shall be made so as to conform neatly to the regular section of the sewer, and nothing will be allowed for any excavation beyond this. All holes or irregularities outside of the regular section must be filled up solid with bricks and mortar, but no extra allowance will be made therefor.

All timbers used in sustaining the excavation must be removed as the brickwork progresses.

Points, by which to get the proper line of the sewer, will be given from time to time as may be needed, and from these the contractor will be required to continue the line of the excavation at his own risk of its accuracy, and to correct at once any errors of alignment that may be discovered before the brickwork is finished.

In tunnels, the quantities paid for will be the earth or rock excavated in the regular section of the sewer, and the brick or stone masonry required for this section, together with any foundation work that may have been expressly ordered, and the amount paid for these items shall be in full for furnishing all materials, and finishing the sewer; the cost of sinking shafts, pumping water, shoring, restoring falls and all accessory works of every kind being borne wholly by the contractor. Those parts only of the sewer will be paid for as tunnels, which are

so marked on the plans exhibited at the time of the letting; all the rest will be paid for as open cut, regardless of the manner in which the work is actually done.

### PIPE SEWERS.

All pipe sewers shall be made of the best quality of vitrified clay pipe with smooth interior surface. Each piece shall be straight or evenly curved, as may be required, and in section shall not vary more than half an inch from a true circle. The thickness of six-inch pipes shall not be less than three quarters of an inch, of twelve-inch pipes, not less than one and one-eighth inches; of fifteen-inch pipes, not less than one and one-quarter inches; and of eighteen-inch pipes, not less than one and one-half inches. Junction pieces, for use in brick sewers, shall be smoothly beveled off to an angle of forty-five degrees, and be not less than two feet long, exclusive of the socket. For pipe sewers the junction piece shall be a part of the main pipe, and no right angle junction shall ever be used.

So far as the specifications for the excavation of trenches, shoring and pumping, preparation of foundations, backfilling and restoring the street surface, already given for brick sewers, can be made to apply to the construction of pipe sewers, they shall be followed.

Each pipe is to be laid on a firm bed and in perfect conformity with the lines and levels given. The bottom of the trench must be shaped so as to fit the lower half of the pipe as nearly as possible, with places cut at the joints for the sockets to rest in, so that the pipe shall have a uniform bearing on the ground from end to end.

The pipes shall be joined by filling the socket with a mortar of pure cement without sand, with only water enough to give it a proper consistency. Great care must be taken to make the joint throughout the lower three-fourths of the pipe perfectly water tight. The upper one-fourth of joint, when so directed, shall be left open.

The interior of the pipes shall be carefully cleaned from all dirt, cement and superfluous material of every description, and a wad made of a sack filled with hay, large enough to fill the pipe and attached to a rod or cord, shall, at all times be kept in the pipe and drawn forward as the work proceeds, care being taken not to loosen the joints.

After the pipes are properly laid and joined, any space between them and the sides of the excavation must be filled with sand, either washed in or well rammed, up to the middle of the pipe. From this point for at least twelve inches above the top of the pipe, the earth shall be filled in so as not disturb the

pipes, and thoroughly rammed; after which, up to the surface, it may be either rammed in layers or thoroughly soaked with water, as may be directed by the sewer commissioner, so that the least possible settling will take place after the work is completed.

Pipe sewers will be paid for by the linear foot of finished work, the price so paid to be in full payment for furnishing and laying the pipe, including the earth excavation, shoring and pumping, backfilling, restoring the street surface, hauling away surplus material, and all other work and material required by the specifications or necessary to give a finished result.

Where rock is encountered in pipe sewers, such rock excavation shall be paid for at the price named herein —— —— —— —— the amount to be estimated with a base of six inches more than the inside diameter of the pipe and the side slope of one horizontal to eight vertical.

**142. Specification for Sewer Pipe.** The following specification for sewer pipe and specials is probably the most carefully worked out of any found in current American practice. While these specifications are very full and complete in many details which are usually overlooked, they are not unreasonably severe. They simply describe clearly what kinds of faults will serve as cause for rejection, and are as valuable to the manufacturer of the pipe in enabling him to select those specimens which he feels will be accepted, as to the inspector himself, who is called upon to accept or reject the material when supplied upon the ground. This specification, therefore, has the great merit of extreme definiteness of meaning, which is the most vital and necessary quality of all specifications. They were prepared by an engineer who knew from experience exactly what could be furnished by the best sewer pipe manufacturers without greatly increasing the cost.

*Sewer Pipe and Specials.*—Pipe sewers are composed of straight sections which are herein termed "*pipe*," and of branches, bends, reducers, etc., which will here be called "*specials*" or "*special pieces.*"

The main sewer, as well as all surface and lot lateral sewers, shall be constructed of the best quality of salt-glazed, vitrified stoneware sewer pipe, and all special pieces that may be required in the work shall be of the same description and quality.

The pipes and specials must be carefully selected and examined by the contractor before or while being delivered upon

the street, and all such material which may be used in the work must conform to the following requirements and conditions:

All hubs or sockets must be of sufficient diameter to receive their full depth the spigot end of the next following pipe or special without chipping whatever of either, and also to leave a space of not less than one-eighth inch in width all around for the cement mortar joint. Pipes and specials which cannot be thus freely fitted into each other shall be rejected.

In the case of pipes and specials of 12 inches and upward in diameter, at least 40 per cent. of all such that will be used in the work must be truly circular or substantially circular in cross-section, and in the case of pipes and specials less than 12 inches in diameter, at least 60 per cent. of the whole number required must be truly circular or substantially circular in cross-section. Of the remainder, in each case, the allowable divergence from a truly circular cross-section shall never exceed the following limits: (*a*) For an *elliptical* cross-section, the greatest internal diameter must not be more than from 6 to 7 per cent. longer than the least internal diameter in the same cross-section. (*b*) For an *oval or egg-shaped* cross-section, the same rule as for elliptical cross-section shall apply. (*c*) Pipes and specials having cross-sections which exhibit *angles, sharp curves* or *flat places* of appreciable magnitude in the circumference, will be rejected.

A single fire-crack, which extends through the *entire thickness* of a pipe or special, must not be over two inches long at the spigot end, nor more than one inch long at the hub or socket end, measured in the latter case from the bottom, or shoulder, of said hub or socket. Two or more such fire-cracks, however, at either end of said pipe or special will cause the same to be rejected.

A single fire-crack, which extends through only *two-thirds of the thickness* of a pipe or special, must not be over four inches long at either end thereof, measured in the direction of its length. Two or more such fire-cracks, however, at either end of said pipe or special will cause the same to be rejected.

A single fire-crack, which extends through only *one-half of this thickness* of a pipe or special, must not be over six inches long at either end thereof, measured in the direction of its length. Two or more such fire-cracks, however, at either end of said pipes or special will cause the same to be rejected.

A single fire-crack, which extends through *less than one-half of the thickness* of a pipe or special, must not be over eight inches long, measured in the direction of the length of such pipe. Two or more such fire-cracks, however, anywhere in the pipe will cause the same to be rejected.

A transverse fire-crack in a pipe or special must not be longer

than one-sixth of the circumference of such pipe, nor shall its depth be greater than one-third of the thickness thereof. Two or more such fire-cracks will be cause for rejection.

No fire-cracks of any description shall, however, be more than one-eighth inch wide at its widest point.

No combination of the foregoing six limitations will be allowed, except with the express consent of the executive board and the city surveyor, as the intent and meaning of these restrictions or limitations is to insure the furnishing of the best marketable quality of pipe and specials by the contractor. In general, any pipe or special which exhibits more than one fire-crack of the magnitudes above mentioned should be rejected at once by the inspector in charge of the work of laying the pipes, unless there be time to make a thorough and minute examination of the other fire-cracks which it may display, and to become thereby convinced that they are of trifling significance.

Any pipe or special which is found to be cracked through its whole thickness from any other cause except the process of burning in the kiln, shall be rejected at once, regardless of the extent of such crack. This refers particularly to damage done by transportation, by cooling or by frost.

Irregular lumps or unbroken blisters on the interior surface of a pipe or special of sufficient size and number to form an appreciable obstruction to the free flow of the sewage, will be cause for rejection. A few small, unbroken blisters, not exceeding one-fourth of an inch in height and one or two inches in diameter, upon the inner surface, need not reject a pipe or special. If there is a broken blister or a flake on the interior of a pipe or special which is thicker than one-sixth of the normal thickness of said pipe or special, and whose largest diameter is greater than one-twelfth of the inner circumference of said pipe or special, the latter shall be rejected. Furthermore, if such broken blister or flake is as large or smaller than just defined, then, unless said pipe or special can be properly fitted and laid so as to bring such broken blister or flake on the top or upper side of the sewer, the said pipe or special shall also be rejected.

Irregular lumps and small, unbroken blisters on the outside of a pipe or special need not reject it. A large and broken blister or a flake on the outside of a pipe or special, which is thicker than one-sixth of the normal thickness of said pipe, and whose largest diameter is greater than from one-ninth to one-twelfth of the outer circumference of said pipe, will cause the same to be rejected. Should, however, the broken blister or flake be within the limits of size just defined, and should the pipe or special admit of being properly laid so as to bring said blister or flake on the upper part of the sewer, then said

pipe or special may be accepted, if otherwise sound in all respects.

Any pipe or special which betrays in any manner a want of thorough vitrification or fusion, or the use of improper materials and methods in its manufacture, shall be rejected. Attention of inspectors is particularly called to the character of the material composing the interior of a pipe or special where the same is exposed by the breaking of a blister, the removal of a flake, or the face of the spigot end of such pipe.

All pipe and specials which are designed to be straight shall not exhibit any material deviation from a straight line. Special curves or bends shall substantially conform to the degree of curvature and general dimensions that may be required.

If a piece be broken out of the rim forming the hub or socket of a pipe or special without injuring the body of such pipe, the latter shall be rejected if the length of said broken piece, or the gap left thereby, is greater than one-tenth of the circumference of said hub. In case that a defect of this nature, and within the limits just defined, occurs in a pipe or special, the latter shall also be rejected unless it can be so fitted in the sewer as to bring said defect on the upper part thereof.

The attention of the inspector in charge of the work of laying the sewer pipe is herewith particularly directed to the foregoing requirements as to the quality of the pipe and specials that will be allowed in the sewer, and in all cases of doubtful interpretation of said requirements, the necessary definitions will be given by the city surveyor and the executive board. Said board also reserves the right to add to the foregoing requirements, at any time during the progress of the work, such further restrictions and conditions respecting the quality of the said pipe and specials as it may deem for the best interests of the taxpayers, in order to secure the best materials which can practically be obtained. All such explanations or definitions of said requirements, in cases of doubtful interpretation, together with all said further restrictions and conditions relating to the quality of said pipe and specials, shall have the same force as though a part of this specification, and the contractor shall be required to comply therewith without extra compensation beyond the prices bid by him for performing the work.

E. K.

**143. Specification for Laying Sewer Pipe.** The following specification for the laying of sewer pipe and specials has all the merits ascribed to the specification for sewer pipe as given in the previous article, and has been prepared by the same engineer. For the purpose of removing any cement mortar

which may have been forced through the joints, and which may, when hardened, form serious obstructions in the sewer, probably no specification will insure such excellent results as that given in the St. Louis specifications for pipe sewers in Art. 139, where the contractor is required to provide "A wad made of a sack filled with hay, large enough to fill the pipe and attached to a rod or cord, which shall at all times be kept in the pipe, and which shall be drawn forward as the work proceeds, care being taken not to loosen the joints." It is an easy matter for the inspector to examine at any time to see whether or not this wad is being drawn forward, and when drawn forward it must of necessity remove any protruding fins of mortar, and leave the interior smooth and entirely free from such obstructions.

Laying the Sewer Pipe and Specials.—Previous to laying the pipe and specials which have been delivered upon the street, into the trench, they shall all be subjected to a rigid inspection by both contractor and inspector, and those which do not come up to the foregoing requirements shall be rejected.

Additional tests by sounding said pipe for cracks, and examining closely all blisters and flakes, shall also be applied. Before lowering the pipes and specials which have passed the inspections, into the trench, they shall first be properly fitted together upon the surface of the street in the order in which they are to be used; and to facilitate the process of laying, the top of each pipe or special, after said fitting, shall be plainly marked with chalk or paint, so that the pipe previously laid in the bottom of the trench shall be disturbed as little as possible.

All pipes and specials in which the spigots and sockets cannot be made to fit together, while on the surface, must be rejected, as no chipping of either socket, hub or spigot will be allowed.

The faces of all spigot ends and of all shoulders in the hubs or sockets must be true, and be brought into fair contact, and all lumps or excrescences on said faces shall be carefully cut away before the pipes are lowered into the trench.

In all cases where the rim of any hub or socket has been broken, as aforesaid, the pipe or special shall be rejected unless it can be so fitted as to bring the broken portion on the top, or upper portion of the sewer. The same condition shall also be applied to the case of broken blisters and flakes, as above mentioned, on either inside or outside of the pipes and specials. All special pieces required in the work, such as

branches, bends, curves, reducers, etc., shall likewise be subject to the same conditions as the straight pipe.

The pipes and specials shall be so laid in the trench that after the sewer is completed the interior surface thereof shall conform on the bottom accurately to the grades and alignment fixed and given by the city surveyor. The main sewer will be divided by man-holes and lamp or hand-holes into a number of distinct divisions or working sections, in each of which the grade and alignment shall, under ordinary circumstances, be truly straight. Changes of grade or direction, or both, in said main sewer will generally be made at man-holes or lamp or hand-holes, although under special conditions, to be defined only by the executive board and city surveyor, such changes may be made at intermediate places.

While the pipe and specials are being laid in each of the aforesaid straight divisions or working sections of the main sewer, a light or a burning lamp must be maintained continually by the contractor at the beginning of such section, and each pipe and specials must be so laid that such light or lamp shall remain constantly in plain view throughout the entire length of such section or division. The same test shall also be applied during the work of refilling the trench, so that when the sewer is in all respects fully completed and accepted by the executive board a light which may be applied at one end of such a division of the main sewer shall be clearly and plainly seen by looking through said sewer from the other end of said division or working section. The length of any such division or the distance between a man-hole and the next following lamp or hand-hole, or between any two consecutive openings of such kind in the main sewer, will, in general, not exceed 300 feet, although in particular cases it may be somewhat greater.

The trenches must, in all cases, be wide enough to admit of the laying of the pipe and specials as above mentioned, and wherever they have not been thus excavated, all necessary widening thereof must be done before the pipe and specials are lowered therein. Ample room or space must likewise be left on each side of said pipe and specials, both to admit of proper refilling underneath and also to allow of free access to all parts of the hub or socket while making the cement joint. Wherever any additional excavation or enlargement in the sides of the trench is required for such purposes, it shall be satisfactorily performed before the pipe and specials are laid or put into place, as no cutting away of the banks will be permitted after any such pipe or special has been set.

Furthermore, before any pipe or special is put into place, a small excavation must be made in the bottom of the pre-

viously graded trench to receive the projecting part of the hub or socket, so that each pipe will have a firm and uniform bearing upon said graded bottom over virtually its entire length. All adjustment of the pipes to line and grade must be done by scraping away or filling in the earth under the body of the pipe, and not by blocking or wedging up the spigot or the hub or socket. Special attention must be paid to this part of the work, since the stability and permanence of the sewer depend largely upon the manner in which the pipes are bedded.

The joints between the individual pipes and specials shall, in all cases, be made water-tight by completely filling out the entire annular space between the exterior of the spigot end and the interior of the hub or socket with hydraulic cement mortar, of such composition as is hereinafter specified. To prevent the mortar from reaching the interior of said pipe, the contractor may if he desires, use a narrow gasket of oakum or hemp, which shall be properly caulked into each joint, after which the mortar shall be introduced therein; but no extra compensation for the use of such gaskets will be allowed. Special care must be taken to secure a perfect filling of the aforesaid annular space at the bottom sides of the pipes, as well as at the top; and previous to the introduction of the mortar, said space, together with the surfaces of the pipe bounding the same, shall be thoroughly free all around from dust, sand, earth, dirt, small stones and water. After said space has been filled as described, a neat and proper finish shall be given to the joint by the further application of similar mortar to the face of the hub or socket, so as to form a continuous and even beveled surface, from the exterior of said socket to the exterior of the connecting spigot all around. The pipes must also be thoroughly cleaned before being laid; and any mortar, earth or other material which may have found its way through a joint or otherwise, into any pipe or special must be carefully removed before the next succeeding pipe is laid, in order that the interior of the sewer shall be left smooth and clean.

As soon as the cementing of any joint, whether in a main sewer or in a lateral sewer, has been completed, the excavation previously made in the bottom of the trench for the reception of the hub or socket must be carefully and compactly filled with sand, loam or fine earth, so as to hold the external mortar finish of said joint securely in its place; and such refilling shall also be carried up around the sides or circumference of the socket, as far as may be necessary. Any water which may have accumulated in said excavations must first be removed, or else said excavations must be completely filled out with the cement mortar specified, in which event no extra compensation will be allowed.

When a pipe or special is used in any main or lateral sewer, which is affected by a broken hub or socket, or a broken blister or flake, or a fire-crack on its exterior surface, as limited and defined in the foregoing, such pipe or special must be set so as to bring said permissible defect on the top or upper part of the sewer; and said defect must thereupon be completely and liberally covered over with a thick layer of hydraulic cement mortar, of the quality specified for the joints, to the full satisfaction of the city surveyor, and the executive board.

As the work proceeds, all of the required specials that are indicated upon the plan of the street, or that may be required during the progress of the work, shall be introduced and set in their proper positions.

Any omissions of the required specials intended to be laid, and indicated upon the plan for the sewer, or that may especially be ordered beforehand by the surveyor, shall be corrected by the contractor without additional compensation; but in case that any special not indicated upon the said plan, or not distinctly required to be introduced beforehand by the surveyor is inserted into the sewer after the latter has been laid, the expense of such insertions will be paid by the executive board upon proper certificate from said surveyor.

Before leaving the work for the night, or during a storm, or for any other reason, care must be taken that the unfinished end of the main sewer, or of any lateral sewer is securely closed with a tightly fitting iron or wooden plug. Any earth, or other materials that may find entrance into said main sewer, or into any lateral sewer, through any such open end or unplugged branch, must be removed at the contractor's expense. The cost of all such plugs, and the labor connected therewith, moreover, must be included in the regular prices bid for the sewers. E. K.

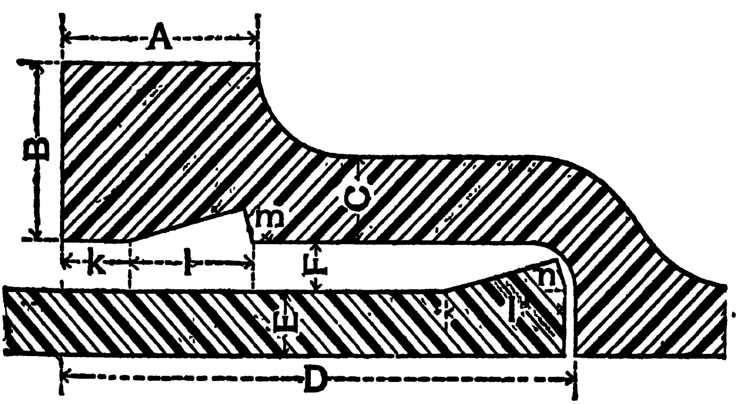
**144. Specifications for the Manufacture and Delivery of Cast Iron Water Pipe.** The following specifications for the manufacture of cast iron water mains are in use in the city of Rochester, N. Y. Although water pipe is now manufactured and sold as a standard article of commerce, and is often purchased without any test or inspection whatever, it must be admitted to be a poor practice, and if the contract is a large one, the material should be thoroughly inspected and tested in all the stages of manufacture. Special attention should be given to the tests of the strength and resilience of the material. When cast iron water mains burst, it is due to a water ram or shock, and the more elastic the material is of which the pipes

are composed, the less will be the force of the ram and the more able the pipes will be to withstand the shock. The resilience of the iron is measured by the product of the strength into the deflection, and in the following specifications both tensile and cross-breaking tests are required, and the requisite deflection in the cross-breaking test is also specified. The deflection here named will insure a very good quality of cast iron, so far as its resilience is concerned, although the strength requirement is not particularly high. The author has had a large experience in testing the strength of cast iron, and he can approve of the standards of strength and resilience here named for water pipe metal:

SPECIFICATIONS FOR WATER PIPE.

*Dimensions and Weight of Pipe.*—The pipe shall be of the kind usually known as "Hub and Spigot," and in general each straight pipe shall be about twelve feet in length from the bottom of the hub to the end of the spigot. No straight pipes will be received that will lay less than 11 feet 8 inches; but it is understood that not more than two per cent. of the total number of pipes required in each class may be 10 feet or more in length, produced by properly cutting off in a lathe a defectively cast spigot end. The form and dimensions of the hub and spigot ends of all pipes and castings shall be subject to the approval of the engineer, when specific drawings therefor are not furnished by him, and shall conform accurately in shape and dimensions to all drawings that may be furnished by him from time to time.

(See accompanying figure for these dimensions for the St. Louis standard water pipe.)



The weights and dimensions of the straight pipes shall conform to the figures in the following table, it being stipulated that the same may be modified at any time hereafter by the engineer:

TABLE OF WEIGHTS AND DIMENSIONS OF STRAIGHT PIPE.

| Nominal internal diameter of pipe. | Class. | Thickness of barrel. | External diameter of barrel | Thickness of lead joint. | Depth of hub. | Standard weight of pipe laying 12 feet: Per lineal foot. | Standard weight of pipe laying 12 feet: Per pipe. | Permitted deviation in weight of pipe laying 12 ft | Maximum weight of pipe laying 12 feet | Minimum weight of pipe laying 12 feet | Deduction from standard weight for each inch of less laying length than 12 feet | Addition to standard weight for each inch of greater laying length than 12 feet. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| in. | | inches. | in | inches. | in. | lbs. | lbs. | p c. | lbs | lbs. | pounds | pounds. |
| 36 | A | 1¼ | 38½ | 7-16 to ½ | 4½ | 492 | 5,904 | 3 | 6,081 | 5,727 | 51 | 41 |
| 36 | B | 1⅛ | 38½ | 7-16 to ½ | 4½ | 444 | 5,328 | 3 | 5,488 | 5,168 | 47 | 37 |
| 36 | C | 1 | 38½ | 7-16 to ½ | 4½ | 397 | 4,764 | 3 | 4,907 | 4,621 | 43 | 33 |
| 30 | B | 1 | 32¼ | ⅜ to 7-16 | 4½ | 330 | 3,960 | 3 | 4.079 | 3,841 | 35 | 26 |
| 20 | | ¾ | | ⅜ to 7-16 | 3¾ | 165 | 1,980 | 4 | 2,059 | 1,901 | 20 | 14 |
| 12 | | 9-16 | | ⅜ to 7-16 | 3½ | 75 | 900 | 4 | 936 | 864 | 8 | 6 |
| 10 | | ½ | | 5-16 to ⅜ | 3½ | 56 | 672 | 4 | 699 | 645 | 7 | 5 |
| 8 | | 7-16 | | 5-16 to ⅜ | 3¼ | 41 | 492 | 4 | 512 | 472 | 4 | 3 |
| 6 | | 27/64 | | 5-16 to ⅜ | 3¼ | 30 | 360 | 4 | 374 | 346 | 3 | 2 |

The specified internal diameter of the pipe is nominal, but no pipe or special casting of any class shall have a less internal diameter than the nominal diameter. The external diameters of all classes of said pipe shall be the same throughout, and all variations in thickness of metal of the shells or barrels shall be made by changing the internal diameter.

The thickness of the metal of the pipe and castings will be measured after they have been thoroughly cleaned, and before being coated. No pipe of any class will be received when the thickness of the metal is over one-sixteenth (1-16) of an inch less in any part than the thickness above specified, or hereafter required by the engineer.

No pipe of full length will be received whose weight is less than the above specified minimum weight, and no excess of weight in any such pipe, beyond the specified maximum weight, will be paid for. It is also expressly understood that the aver-

age weights of the straight pipe of the several classes shall not exceed the said standard weights by more than two per cent. of the latter, and that no greater over-weight than this percentage will be paid for in the final settlement. The standard weight of the straight pipes will depend upon the laying length of the pipes actually furnished, and will be determined by the engineer.

*Quality of Metal.*—The materials, details of manufacture, and the testing of all pipe and special castings herein referred to, shall at all times be subject to the inspection and approval of the engineer. The metal, which must be remelted in the cupola or air furnace, shall be made without admixture of cinder-iron or other inferior metal, and shall be of such character as to make a pipe strong, tough, and of sound, even grain, free from uncombined carbon when examined under the microscope, and such as will satisfactorily bear drilling, chipping and cutting. Its tensile strength and resilience, when tested in proper samples, shall meet all the requirements hereinafter expressed.

Specimen rods of the metal used, of a size and form suitable for a testing machine, shall be made and carefully tested to ascertain its tensile strength. Another set of test bars, each being twenty-six (26) inches long, two (2) inches wide, and one (1) inch thick, shall also be made as often as the engineer shall direct, and shall be tested both for transverse strength and deflection by placing them horizontally and flatwise upon supports twenty-four (24) inches apart, and then applying a steadily increasing load at the middle of each bar.

The bars for testing the transverse strength or resilience of the metal shall be cast from regular patterns in dry or green sand, and as nearly as possible to the required dimensions without being finished up; proper corrections will, however, be made in the results for slight variations of width and thickness. The rods for testing the tensile strength of the iron, on the other hand, must be turned down on a lathe in order to remove the rough exterior and enable the diameter to be accurately measured.

At least one set of four test bars, of each kind above designated, shall be made and tested as described on each working day during the manufacture of the pipes and specials. These test bars must be poured from the ladle either before or after any particular pipes or special casting are poured, and must present true samples of the iron used in said pipes or castings. Records shall be kept of the tests of all bars made, and a duly certified copy of such records shall be forwarded weekly to the engineer.

The quality of the metal used for the pipe and specials must be such that said bars for testing resilience, as aforesaid,

shall each carry a center load of not less than nineteen hundred (1,900) pounds before breaking, and exhibit a deflection of not less than five-sixteenths (5-16) of an inch; also that the tensile strength of said metal shall be at least 17,000 pounds per square inch, as determined by the tests with the first named set of rods. In estimating the suitability of the metal from said tests, the average of the three highest results obtained from each set of four bars will be considered as representing the actual strength of the iron.

*Manufacture of Pipe and Special Castings.*—All the straight pipes shall be cast in dry sand moulds, vertically with the hub end down. Every pipe is to have the initials of the maker's name cast distinctly upon it, and also the year, the class letter, and a number signifying the order of its casting, in point of date; the several different classes of pipe each to have its own series of numbering; the figures and letters to be at least two inches in length, with a proportionate width; the weight of each pipe to be conspicuously painted on the outside, before delivery, with white lead paint at the contractor's expense.

The branches and all other special castings must conform in weight and thickness of iron to the drawings and directions to be furnished by the engineer, and no allowance will be made for making or altering patterns for the pipe or any special castings, or for any machine work in properly facing and drilling flanges, etc., where bolted joints are to be made. All required machine work on said castings shall be done in the best and most workmanlike manner, in accordance with said plans and directions of the engineer, and to his entire satisfaction. Said castings shall be subjected to the same examinations and tests at the foundry, except the water-pressure proof, as the straight pipe, and shall be marked in a similar manner. The engineer may reject, without proving, any pipe or casting which is not in conformity with the specifications or the drawings furnished.

Pipes and special castings shall not be taken from the pit and stripped while still showing any color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal cooling and contraction by subsequent exposure.

On being removed from the flasks, all pipes and special castings shall be subjected to a careful examination and hammer test for the purpose of detecting imperfections of any kind. They shall then be thoroughly dressed and made clear and free from earth, sand or dust, which adheres to the iron in the moulds; iron wire brushes must be used, as well as softer brushes to remove the loose dust. No acid shall be used in cleaning the castings. After having been properly dressed and cleaned, they shall again be subjected to a thorough inspection

and hammer test. The contractor will be required at the foundry to place all castings in such positions as may be deemed necessary by the engineer for convenience of inspection.

The pipes and special castings shall be free from scoria, sand-holes, air-bubbles and other defects or imperfections; they shall be truly cylindrical in the bore, straight in the axis of the straight pipes, and true to the required curvature or form in the axis of the other pipes; they shall be internally of the full specified diameters, and shall have their inner and outer surfaces concentric. To insure proper diameters of sockets and spigots, a circular iron templet of the required dimensions shall be passed to the bottom of every socket, and a circular ring over every spigot. Care shall also be taken to avoid all excess in diameter of the sockets. No pipes or special castings will be accepted which are defective in joint room, whether in consequence of eccentricity of form or otherwise. No lump or rough places shall be left in the barrels or sockets, and no plugging or filling will be allowed. All pipes and special castings with defective hubs or flanges will be rejected.

When a defective spigot end is to be cut off from any straight pipe, such cutting must in all cases be done in a lathe, and a suitable bead or fillet of half-oval wrought iron, about three-fourth (¾) inch wide and five-sixteenths (5-16) inch thick shall be shrunk upon the new end of the pipe; and there shall be deducted from the proper original weight of the pipe an amount as determined from the rate specified in the foregoing table.

*Coating the Pipe and Special Castings.*—After the above described cleaning and inspection, every pipe and special casting shall be heated in a suitable oven to a temperature of about 320 degrees Fahrenheit and, while at this temperature, be immersed in a bath of hot coal tar pitch varnish, prepared in general according to Dr. R. Angus Smith's process. Special care shall be taken to have the surfaces of all pipes and castings entirely clean and free from rust immediately before putting them into said bath. If any pipe or casting cannot be dipped in said bath soon after its removal from the mould, it shall at once be thoroughly coated with pure linseed oil in order to prevent the formation of any rust before applying said varnish.

The varnish above mentioned shall be made from coal tar, distilled until the naptha is entirely removed and the material deodorized, also until it attains the consistency of wax when cold. Pitch which becomes hard and brittle when cold will be rejected. To this material from five to six per cent. of its weight of pure boiled linseed oil shall be added and thoroughly

boiled therewith. The relative portions of pitch and oil, as well as the details of mixture and boiling, are to be carefully determined by experiment.

The coating must be durable, smooth, glossy, hard, tough, perfectly waterproof, not affected by any salts or acids found in the soil, free from bubbles or blisters, strongly adhesive to the iron under all circumstances, and with no tendency to become soft enough to flow when exposed to the sun in summer, or to become so brittle as to scale off in winter. As one test of the quality of the coating, a properly coated specimen casting will be plunged into a freezing mixture, and kept therein until the metal has acquired the temperature of said mixture, after which the casting shall be well hammered. If the coating remains tough and adheres closely to the metal, it will be considered proper, provided that it be satisfactory in all other respects.

After a varnish of the proper quality has been obtained, it shall be heated in a suitable dipping tank to a temperature of about 300 degrees Fahrenheit, or such other temperature as may be found expedient, and shall be maintained thereat uniformly during the time of dipping. Fresh materials must be added from time to time in the right proportions to keep the mixture of the proper consistency. The exact proportions will be determined by the engineer, and will be varied also according to the season of the year, as may be directed by the said engineer, or found necessary to produce a coating of the required quality. The tank shall also be occasionally emptied of its contents and refilled with fresh material, the frequency of such operation depending both on the character of the mixture and the manner of conducting the coating process.

Every pipe and special casting, after having been inspected, cleaned and dressed as above described, shall be heated in a suitable oven to a temperature about 20 degrees Fahrenheit higher than that which was found most expedient for the bath of coating material aforesaid, and while at such temperature, shall be immersed or dipped in said bath. All pipes or castings shall remain in the tank at least twenty (20) minutes, or as much longer as may be necessary to insure the soundness of the coating.

Whilst any pipe or casting remains in said bath, the hot mixture must be kept thoroughly stirred by a frequent rolling, turning or churning motion of such casting, and upon its removal from the tank, the coating shall fume freely for a short time, and set perfectly hard within one hour thereafter. Proper facilities for handling the castings and allowing all surplus material to drip off, shall be provided by the contractor. The cost of all labor and material involved in the coating of the

pipes and castings must be included in the prices bid for furnishing said pipes and castings.

*Testing.*—After the said coating has become thoroughly set and hard, every pipe shall be subjected to a proof by water-pressure of from 200 to 300 pounds per square inch, according to its class and diameter, and as will be determined by the engineer. Each pipe while under the required pressure, shall be sharply rapped from end to end with a hand hammer, to ascertain whether any defects have been overlooked; and any pipes which may exhibit any defects by leaking, sweating or otherwise, shall be rejected.

All the above inspections, manipulation and tests of the pipe and test bars shall be made at the expense of the contractor for the pipe, said expense, however, not to include salary of any inspector who may be appointed by the executive board. If required by the said board, the affidavit of the superintendent of the foundry, or that of the foreman employed by him to perform the above described testing, shall also be furnished to the engineer from time to time; said affidavits to be recorded upon the pipe inspector's sheets, and stating in detail that the pipes or castings therein described have been carefully tested at the foundry in accordance with these specifications, and that no defects were discovered or discoverable.

*Weighing for Payment.*—The pipes and castings will be weighed for payment after all cleaning, dressing and machine work has been done and the coating has been applied, and the contractor must furnish, at his own expense, accurate and properly sealed scales, together with the necessary labor for the purpose. The executive board also reserves the right to reweigh on similar scales, any pipe or casting upon or after its arrival at the designated point of delivery; and if any discrepency be discovered between the weight marked upon said pipe or casting and that which was found on such re-weighing, the latter weight will be adopted in the final settlement. Payment for all material furnished in accordance with these specifications will be made at the prices bid per net ton (2,000 pounds) for straight pipe and special castings.

*Transportation of Pipes and Castings.*—All pipes and castings must be delivered in all respect sound and in conformity with these specifications. Upon their delivery at the point designated, the executive board reserves the right to subject the said pipe and castings to the same water-pressure proof and hammer tests as are above specified to be applied at the foundry; and all defective pipes or castings which may have passed the inspector at the foundry, or which may have been broken in transportation from the foundry to said point of delivery, will be rejected when there discovered, unless the same

may be cut as hereinafter provided. Care must also be taken in handling the pipes and castings not to injure the coating, and no material of any kind shall be placed in said pipes and castings during transportation, or any time after being coated.

If, upon its arrival at the designated point of delivery, the spigot end of any straight pipe should be found cracked or broken, during transportation from the foundry to the said point or otherwise, such defective portion will be cut off at the contractor's expense, provided that the same does not exceed a length of four (4) feet, and a suitable fillet or bead shall then be shrunk on the new spigot end, as above specified, A deduction from the proper original weight of such pipe shall also be made in each such case at the rate specified in the above table for every inch of length so cut off. No pipe or special casting in which the hub is found to be cracked or defective in any respect, will be accepted at said point of delivery or elsewhere; nor will any special casting with a defective spigot end be received, or permitted to be cut off, without the written order of the engineer. E. K.

**145. Specifications for Laying Water Pipe.** The following clauses referring to the methods of laying water pipe, and making the joints, are taken from the complete specifications on this subject used by the water commissioner of St. Louis. All that portion of the specification referring to the trenching, protection, tools, alignment, grades, connections, back-filling, etc., together with the general clauses are here omitted.

The reducers, bends, caps and such other parts as are liable to draw, shall be firmly secured by straps and bolts, and in addition to this a firm blocking shall be set behind all caps, curves, fire hydrants and three way branches, said blocking to have a large surface bearing against the undisturbed earth, and to be wedged up tight. All applications necessary to the perfect working of the distribution, when the water is let on, shall be made and completed,

The straps and bolts used shall be made from the best American refined iron, and the size and workmanship, as well as the material, shall be in all respects satisfactory to the water commissioner.

Any omission of branches, stop-cocks, or other appurtenances intended to be laid, shall be corrected when required, by re-opening the trench, if it has been filled up, and introducing what may have been omitted.

At the time when laid, the spigots of the pipe shall be so adjusted in the sockets as to give a uniform space all around,

and if any pipe does not allow sufficient space, it shall be replaced by one of proper dimensions. The joint shall, at all points, be at least five-sixteenths of an inch in thickness. In the lead and gasket joints, the depth of lead shall not be less than three and one-quarter inches for the fifteen inch pipes and over, nor less than two and three-quarters inches for smaller pipes. Gaskets of clean, sound hemp yarn, braided or twisted, and tightly driven, shall be used to pack these joints; when required, a space of one-quarter inch shall be left between the contiguous pipes.

The lead used shall be of the best quality of pure and soft lead, and suitable for caulking and securing a tight and permanent joint.

Before running the lead, the joints shall be carefully wiped out to make them clean and dry; the joint shall be run full at one pouring, and the melting pot shall always be kept within fifty feet of the joint about to be poured.

The joint shall be caulked by competent mechanics. The caulking to be faithfully executed, and in such a manner as to secure a tight joint without overstraining the iron of the bell. In all cases the caulking shall be done *towards* the place of the gate and other points where the lead is likely to be porous, so as to drive it together at these points The lead, after being driven, shall be flush with the face of the socket.

The pipes and all other castings shall be carefully swept and cleaned, as they are laid, of any earth or rubbish which may have found place inside, during or before the operation of laying. Every open end of a pipe shall be plugged or otherwise closed before leaving the work for the night.

In refilling the trenches, the earth filled into the bottom of the trench, under and to the top of the pipes and other castings, shall be carefully packed and well rammed with proper tools for the purpose.

Whenever written directions so to do are given, the contractor shall fill the trench with river sand, said filling to be done in exact accordance with the orders and directions of the water commissioner. For all sand filling done as above, the sum of $—— per cubic yard will be paid, which sum shall include all expense of materials, tools and labor for the sand filling, and removing the surplus earth from the work.

Care shall be taken to give the pipe a solid bearing throughout its entire length. The earth filling above the pipes shall also be sufficiently packed and rammed to prevent after settlement, and the material used shall be free from stones or rock fragments. The trenches shall, in all cases, be refilled with the material furnished by their excavation, provided that it be of a proper quality, and the necessary haul be not more than 500

feet. Earth borrowed or hauled over 500 feet, to refill the trenches (excepting trenches where rock has been excavated), will be paid for as embankment, at the price given under item of section seven.

In streets and roads, the class of surface before existing shall be replaced so as to be in every way equal to that surface in materials and workmanship, and satisfactory to the water commissioner.

Whenever trenches are excavated in or across streets paved with granite or wood blocks, or with asphalt, the contractor will be required to have the back-fill of trench thoroughly rammed (not less than three men ramming to each man filling the trench), and to replace the paving temporarily, so as to make the street passable for traffic; the permanent laying of the pavement in these cases, will be assumed by the city.

A wooden box or vault shall be furnished and set over each of the stop cocks, air cocks, and fire hydrants, and the iron frames and covers shall be properly fastened to them. These boxes are to be made of the form and dimensions shown by samples furnished and approved by the water commissioner; they shall be made from sound, well seasoned oak lumber; the corner posts shall be of four-inch scantling, and the sides shall be formed from two-inch plank, set close, and securely nailed. M. L. H.

**146. Specifications for Stop Valves.** The following specifications for stop valves for water mains are thought to be particularly strong in the requirements governing the strength of the material used in the different parts. These requirements are followed up very carefully by numerous tests of the strength of the material, and in this way the character of the composition metal used has come to be very superior to that formerly employed, and much superior to that which would be obtained without such rigid specifications and tests. They are the standard specifications used in the St. Louis water department.

All the iron castings shall be made from a superior quality or iron, remelted in the cupola or air furnace, tough and of even grain, and shall possess a tensile strength of not less than 18,000 pounds per square inch.

Test bars of the metal 3 inches by ½ inch when broken transversely, 18 inches between supports and loaded in the center shall have a breaking load of not less than 1,000 pounds, and shall have a total deflection of not less than 3-10 of an

inch before breaking. Said bars to be cast as near as possible to the above dimensions without finishing, but correction will be made by the water commissioner for variations in thickness and width, and the corrected result must conform to above requirements.

Specimen bars of the metal used, of a size and form suitable for testing, shall be prepared when required.

These specimen bars shall be poured from the ladle at any time, either before or after the casting has been poured, as may be required, and shall present a true specimen of the iron used for making the castings.

If any two test bars cast the same day do not show the required cross breaking load and deflection, all the castings made from the same mixture to be rejected.

Each valve shall have the maker's initials, the numbers showing point in time of casting, and the year cast upon it. The year above and the number below, thus:

$$\frac{1890}{1} \qquad \frac{1890}{2} \quad \text{etc.}$$

The figures and letters will be from 2 to 2½ inches long, and shall have at least ⅛ inch relief.

All the wrought iron used shall be of the first quality of American refined iron.

All the composition metal used, except the valve stem, shall be composed of the following proportions, viz: 85 per cent. copper, 10 per cent. tin, and 5 per cent. spelter; and shall have a tensile strength of not less than 22,000 pounds per square inch, with 5 per cent. elongation in 8 diameters, and 5 per cent. reduction of area at breaking point.

All castings must conform in shape and dimensions to the drawings. The castings must be clean and perfect, without blow or sand holes, or defects of any kind. No plugging or other stopping of holes will be allowed.

The valve guides must be straight and smooth. Irregularities, if any, must be planed or chipped off smooth. All face joints must be planed true and smooth, in the most workmanlike manner, so as to make a perfectly water-tight joint, with a *very thin* layer of strictly pure lead cement.

All bolt holes must be accurately drilled from templates. The upper part of valve to be finished to receive the valve stem, collar and stuffing box, and the fitting at this point must be such as to secure a perfect working joint.

The valve to be a two-faced wedge valve; the castings for same to be as shown on drawing. The raised rims to be turned true with dovetailed channel to hold the composition rings. The faces must be brought to the exact angle before the rings

are put on. The face rings are to be of composition metal, of quality hereinbefore specified, and are to be turned to fit the dovetail in the iron wedge. The composition rings of valves must be shrunk on, and also fastened by copper studs, placed not over three inches apart—the whole to be then brought to a true plane surface.

The upper portion of the wedge to be arranged to receive the composition nut as shown. Care shall be taken to give the composition nut a perfect bearing surface—both top and bottom.

On the 36 inch and 30 inch valves, the brass bearings of side guides shall be of the full dimensions, and have the exact clearance shown on drawings, and be secured in place by countersunk copper studs, placed not over three inches apart, after which the guides shall be brought to a true and smooth surface.

The seats for rings in body of valve shall be turned true and smooth, and to the required angle as shown on drawings.

The seat rings shall be of form and dimensions as shown on drawings, and faced true and smooth. Seat rings to be forced into position and thoroughly and securely fastened in place, and a perfectly water-tight joint secured.

All valves of 10 inch diameter and upwards to be provided with indicator as shown on drawings.

All wrought iron bolts and nuts to be made from the best quality of American refined iron. The nuts to be hexagonal and the heads square. Heads, nuts and threads to be standard size.

Valve stem shall be made of phosphor bronze, quality B; or Crescent bronze, quality No. 2; or of first quality of "Stucksteele" bronze, and shall be free from flaws or defects of any kind, and have a tensile strength of not less than 30,000 pounds per square inch. Screw threads on the stems and nuts to be cut in most perfect manner, and of the exact pitch shown on the drawings, and so as to work true and smooth, and in perfect line throughout entire lift of valve.

There shall be two dowel pins, made of composition, set in the flanges connecting the dome and main casting, as shown on drawings, for the purpose of centering and bringing into perfect alignment these castings. Holes for dowel pins to be drilled and reamed tapering, and pins turned to perfect fit. Pins for the 36 inch and 30 inch to be 1 inch in diameter; for the 20 and 15 inch, ¾ inch diameter; for the 12 and 10 inch, ⅝ inch diameter; and for the 8 and 6 inch, ½ inch diameter.

Gearing to be extra strong, and of the form and dimensions shown. Pinion post to be of a good quality of steel; key seats shall be truly cut, and keys made of steel, and of the full dimensions.

Cap nuts for valve wrench to be of the following outside dimensions: for all 6 to 15 inch valves (inclusive), to be 2 inches square; for the 20 inch, to be 2¾ inches square; and for the 30 and 36 inch, to be 3¼ inches square.

All iron work, after being thoroughly cleaned, to be painted with three good coats of paraffine varnish, applied hot. The valves shall be tested by hydraulic pressure, as follows:

*First.* Heads shall be secured at each end of casting, the valve opened, and a pressure of 200 pounds per square inch applied.

*Second.* Each face joint of valve shall be tested by closing the valve, leaving one end of the casting open, and applying a pressure of 100 pounds per square inch to the other—this operation to be reversed to test the other face.

Any and all defects developed in testing shall be thoroughly corrected to the satisfaction of the water commissioner. After testing all valves to be thoroughly drained.

All parts of valves of the same size to be perfectly interchangeable.

The water commissioner may take at random any wrought iron bolt or nut, and have it broken in a testing machine. If bolt shall not fulfill the requirements of table below, the whole lot of that size and make to be rejected:

| Size of Bolt. | Tensile Breaking Strength | Reduction of Area at Breaking Point |
|---|---|---|
| 5-8 inch. | 9,000 lbs. | 20 per cent. |
| 3-4 " | 13,000 " | 20 per cent. |
| 7-8 " | 19,000 " | 20 per cent. |
| 1 " | 25,000 " | 20 per cent. |
| 1 1-8 " | 31,000 " | 20 per cent. |
| 1 1-4 " | 40,000 " | 20 per cent. |
| 1 1-2 " | 58,000 " | 20 per cent. |

The water commissioner may take at random any valve stem with nut, either finished or unfinished, for 6, 8, 10 or 12 inch valves, and have it broken in a testing machine.

If any stem or nut shall not fulfill the requirements of the table below, the whole lot of that make and size to be rejected:

| Size of Valve. | Tensile Breaking Strength of Stem. (Including Nut and Collar) | Ductility in 8 Diameters. |
|---|---|---|
| 6 inch. | 34,000 lbs. | 8 per cent. |
| 8 " | 34,000 " | 8 " |
| 10 " | 34 000 " | 8 " |
| 12 " | 42,000 " | 8 " |

All valve stems for 15 inch and larger valves to be cast with a coupon on one end, 15 inches long by 1½ inches diameter. Any one or all of these coupons may be taken by the water commissioner and broken in a testing machine. If any coupon shall show a breaking strength of less than 30,000 pounds per square inch, or shall have a ductility of less than 8 per cent. in 8 diameters, the stem from which it was cut shall be rejected.

For all materials taken by the water commissioner for testing which are found to conform to the above requirements, there shall be added to the final estimate:

| | |
|---|---|
| For all wrought iron | 7 cents per pound. |
| For all Phosphor bronze | 25 cents per pound |
| For all Crescent bronze | 25 cents per pound. |
| For all Stuckstede bronze | 25 cents per pound. |

The broken material to belong to the party of the second part. For all materials taken for testing which do not come up to requirements there shall be no allowance, and the broken material shall be returned to party of the first part.[1]

The whole to be put together in a thorough and workmanlike maner, and delivered, packed, ready for use. The working parts to be perfectly fitted together and working true in line. The joint between the face rings, when the valve is closed, must be absolutely water-tight. The whole to be in material, workmanship and finish, to the satisfaction and acceptance of the water commissioner. M. L. H.

## LUMBER GRADING AND CLASSIFICATION.

**147. Rules of the Southern Lumber Manufacturers' Association.** The rules given in the following articles were adopted by the Southern Lumber Manufacturers' Association at Memphis, Tennessee, February 21, 1895. They are given here entire to assist the engineer to use descriptive terms in the same sense in which they are used by the lumber manufacturers and dealers. While they are intended to apply only to southern yellow pine, they can be understood to apply in a general way to all merchantable lumber. Since lumber is always sold under certain grade names, and since in the large

[1] In the St. Louis specifications the contractor is the party of the first part.

markets the lumber is officially graded, it is sufficient for the engineer and architect to use these technical terms in his specifications, provided he knows that he is using it in the same sense in which it is used by lumber dealers in that market. If he does not feel safe in limiting his description to the use of such technical class terms, he will still find considerable information in the following official rules, which will enable him better to describe the kind of lumber which he wishes to have supplied.

**148. General Rules for Classifying Lumber.** The following general rules are intended to serve as a guide to lumber inspectors in enabling them to classify the lumber in accordance with the grades named below in subsequent articles.

1. Yellow pine lumber shall be graded and classified according to the following rules and specifications as to quality; and dressed stock shall conform to the subjoined table of standard sizes, except where otherwise expressly stipulated between buyer and seller.

2. [1]Recognized defects in yellow pine are knots (pin, round, spike, black, encased, loose or rotten), knot holes, splits (either from seasoning, ring-heart or rough handling), shake, wane, crooks, warp, rotten streaks, dote, rot, worm holes, pitch pockets, seasoning or kiln checks, blue sap and pitch streaks.

3. Bright sap shall not be considered a defect in any of the grades provided for and described in these rules. The restric-

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[1] Some of the following terms may need defining Ring-heart is a "shake" or cleavage along the plane of an annual ring, usually about half way between the pith and the circumference. "Shake" or "wind shake" is a cleavage of the trunk of a tree while yet standing, due to the action of the wind in bending the trunk. It is usually along the plane of an annual ring; that is to say, concentric with the center or pith of the tree.

"Heart-shake" is a diametral or radial cleavage through the tree or log If it occurs after the logs are cut, or in large timbers after they are sawed, it is due to shrinkage in drying. This is the common defect of all oak logs or large timbers.

"Wane" is a deficiency in width, either over the entire edge or on one corner, caused by a crook in the log.

"Crooks" are permanent distortions of the board, due to defective piling or from other causes.

"Warp" is a twisting of the board into a warped surface.

"Seasoning or kiln checks" are either very small or large cracks, caused by drying the surface of the board with its accompanying shrinkage, while the interior is still wet.

"Blue sap" is a discoloration, which green yellow pine is subject to, especially the sap portion, if not at once piled for drying or placed in a dry kiln.

"Pitch streaks" are longitudinal openings, sometimes of considerable size, as ⅛ inch to ¼ inch wide and several inches (or even feet) long, filled with rosin.

tion or exclusion of bright sap constitutes a special class of material which can be secured only by specific contract.

4. Firm red heart shall not be considered a defect in common grades.

5. Defects in rough stock, caused by improper manufacture or drying, will reduce grade, unless they can be removed in working such stock to standard sizes.

6. Imperfect manufacture in dressed stock, such as chipped, grain splintered or torn places, broken knots on edge of shiplap, insufficient tongue on flooring, etc., shall be considered defects, and reduce grade accordingly.

7. A standard knot is sound, and not over 1¼ inches in diameter. A pin knot is sound, and not over half an inch in diameter.

8. Any piece that will not work one half its size shall be classed as a dead cull.

9. The grade of all regular stock shall be determined by the number and position of the defects visible in any piece. The enumerated defects admissible in any given grade are intended to be descriptive of the coarsest pieces such grade may contain. The average quality of the grade should be midway between such pieces and the defects allowed in the next higher grade.

10. Lumber or timber sawed for specific purposes, such as wagon tongues, bridge timbers, car sills, etc., must be inspected with a view to the adaptability of the piece for the use intended.

11. In finishing, flooring, etc., the enumerated defects admissible in a given grade apply only to the face side of the piece, but reverse face should not admit defects that would render the piece unsuitable for the purpose intended.

12. Standard lengths are multiples of 2 feet from 10 to 20 feet, inclusive, for boards and strips, and from 10 to 24 feet, inclusive, for dimension, joists and timbers. Longer or shorter lengths than those herein specified are special. Odd lengths, if below 24 feet, shall be counted as of the next higher even length.

13. On stock width shipments of 8-inch and under no board shall be admissible that is more than ¼ inch scant; on 10-inch not more than ⅜ inch, and on 12-inch not more than ½ inch scant of specified width.

14. Yellow pine of better grade than No. 1 common up to 4 inches in width is classified according to grain as edge grain and flat grain. Edge grain yellow pine has been variously designated as rift-sawn, straigth grain, vertical grain and quartersawed, all being commercially synonymous terms. Edge grain stock is specially desirable for flooring, and admits no piece in which the angle of the grain exceeds forty-five degrees from vertical, thus excluding all pieces that will sliver or shell from

wear. Such stock as will not meet these requirements is known as flat grain.

15. All dressed and matched stock shall be measured and sold "strip count," *i. e.*, full size of rough strip from which such stock is made—3, 4, 5 and 6 inches wide.

16. The foregoing general observations shall apply to and govern the following detailed descriptive enumeration of recognized grades.

**149. Rules for Grading Finishing Lumber.** The following rules for grading apply to all kinds of finishing stock, whether for interior or out-door work. In these rules such expressions as "S. 1 S." or "S. 2 S." mean "surfaced one side," or "surfaced two sides," respectively. Also "S. 1 S. 1 E." will be understood to mean "surfaced one side and one edge." By surfacing is meant planing or running it through a planing machine. It may still require hand dressing for the best work. Nearly all saw mills now dry their lumber and run it through the planer, in order to save the extra freight on the rough and green lumber.

(Grades: First and second clear; third clear; barn and roofing stocks.)

17. *First and Second Clear Finish,* 1 inch, S. 1 or 2 S., up to and including 10 inches wide, must show one face clear from all defects; 33 1-3 per cent. of any shipment of 12 or 14 inches wide will admit two pin knots or one standard knot, slight pitch streak, or small pitch pocket, or sap stain not over 1½ inches wide running across the face, or small kiln or seasoning checks, but no two of these defects shall appear in a single piece; 16 inches wide will admit of two defects allowed in 12-inch or their equivalent. Wider than 16-inch will admit proportionately more defects. Pieces otherwise admissible in which the point of the grain has been loosened or slivered in dressing on the face side should be put in lower grade. Defective dressing or reverse face of finishing is admissible. In case both faces are desired clear special contract must be made.

18. *Third Clear Finish,* 1 inch, S. 1 S or 2 S., up to and including 10 inches in width, may have not more than two, of the following defects on best or face side: Three pin knots one standard knot; three sap stains 2 inches wide running across the face or their equivalent; two pitch pockets; slight pitch streaks, kiln or seasoning checks; torn places, and wane which does not enter more than 1 inch, nor extend more than 2 feet;

12-inch will admit three of the above defects, or their equivalent. This grade is suitable for paint finish.

19. $1\frac{1}{4}$, $1\frac{1}{2}$ and 2 inch, S. 1 or 2 S., shall take 1 inch inspection, and unless otherwise agreed between buyer and seller, shall be subject to inspection on face or best side only.

20. Barn and novelty siding, shiplap and grooved roofing shall be 8, 10 and 12 inches wide, and consist of boards falling below third clear which are sound and water-tight, free from coarse knots and wane over 1 inch wide extending more than 3 feet in any piece. Pitch, except in narrow streaks, should be excluded.

21. *Edge-Grain Flooring.* (Grades: First clear, second clear.) First clear edge-grain flooring must be well manufactured, and free from all defects on face side of strip.

22. Second clear edge-grain flooring will admit of three pin knots or one standard knot, or small pitch pocket, or blue sap stain not to exceed 10 per cent. of the face.

23. *Flat-Grain Flooring.* (Grades: A flat, B flat.) A flat flooring may contain two pin knots or one small pitch pocket, but shall be free from other defects, and must be well manufactured. Pieces in which the point of the grain has been loosened in dressing should be put in lower grade.

24. B flat flooring may have any two of the following defects: Three pin knots or one standard knot, slight sap stains, small pitch pockets, slight torn places and defects in manufacture, narrow pitch streaks and seasoning checks. When all other defects are absent, blue sap stain in any quantity shall be admitted.

25. *Common Flooring.* (Grades: No. 1 common, No. 2 common.) No. 1 common flooring must be manufactured from sound stock. In addition to the defects described in B flat, also admits of sound knots, blue sap and firm red heart in any quantity, pitch and slight shake, but must lay without waste. No division as to grain is made in this grade.

26. No. 2 common flooring includes all pieces that will not grade No. 1 common which can be laid without wasting more than one-fourth the length of any piece. This grade will admit imperfections which do not render the piece unfit for use in cheap floors and roof sheathing.

27. Center-matched flooring shall be required to come up to grade on one face only.

28. *Ceiling.* (Grades: A, B, C.) A ceiling shall be free from all defects on face side and well manufactured.

29. B ceiling will admit slight imperfections in dressing—three pin knots or one standard knot, pitch streaks or small pitch pockets, or blue sap stain not to exceed 10 per cent. of the

face; but not more than two of these defects to be admitted in any piece.

30. C ceiling conforms to grade of No. 1 common flooring and is suitable for paint finish. Will admit imperfections that do not prevent its use without waste.

31. *Wagon Bottoms.* (Grades: A, B.) Wagon bottoms shall be graded the same as flat grain flooring.

32. *Bevel and Drop Siding.* (Grades: A, B and C.) Shall be graded according to ceiling rules, but will admit more blue stain, and, except in C grade, should exclude pitch. Slight additional imperfections on the thin edge of bevel siding which will be covered by the lap are admissible.

33. *Partition.* (Grades: A, B and C.) Partition shall conform to ceiling grades, but must meet the requirements of the specified grade only on one face. The reverse face shall not be more than one grade lower.

34. *Molded Casings and Base.* (Grades: First clear, second clear.) First clear shall be free of all defects on face and perfect in manufacture.

35. Second clear is suitable for work that is to receive a paint finish, and usually consists of rejections, made after dressing, from stock inspected in the rough as first clear. The defects admitted in B ceiling would be allowed.

### 150. Rules for Grading Common Boards and Rough Lumber.

COMMON BOARDS AND SHIPLAP.

36. No. 1 common boards, S. 1 S., and No. 1 common shiplap shall be manufactured from sound stock, of even thickness the entire length. Will admit of any two of the following defects: Wane one-half inch deep on edge and one-sixth the length of any piece; tight sound knots, none of which shall be larger than three inches in diameter, or equivalent spike knots; one split not more than sixteen inches long, and blue sap. These boards should be firm and strong, suitable for use in all ordinary construction and serviceable without waste.

37. No. 2 common boards and No. 2 common shiplap admit pieces that fall below No. 1 common which are free from the following defects: Rotten streaks that go through the piece, through heart shakes which extend more than one-half the length of the piece, and wane over two inches wide exceeding one-third of the length of the piece. A knot hole 1½ inches in diameter or its equivalent will be allowed, provided the piece would otherwise grade No. 1 common. Worm holes and straight splits one-fourth of the length of the piece are admissible.

FENCING S. 1 S.

38. No. 1 common fencing must be manufactured from sound stock. May contain sound knots equal in diameter to not over one-third the width of piece at any given point throughout its length, but must be free from spike knots the length of which is over one-half the width of piece. Also, free from wane over one-half inch deep on edge and one-half the length of any piece measured on one side. This grade must work its full length without waste.

39. No. 2 common fencing shall admit of pieces that fall below No. 1 common which are free from through rotten streaks.

40. Miscut 1 inch stock in boards and fencing which does not fall below ¾ inch thick shall be admitted in No. 2 common, provided that the grade of such thin stock is in all other respects as good as No. 1 common.

DIMENSION S. 1 S. 1 E.

41. *No. 1 Common Dimension* shall be manufactured from sound stock, and be free from loose and unsound knots, and large knots so located as to materially impair the strength of the piece; will admit of seasoning checks and heart shakes that do not go through, of slight wane and such other defects as do not prevent its use as substantial structural material.

42. *No. 2 Common Dimension* admits all pieces falling below No. 1 common which are free from through rotten streaks, and sound enough to be used without waste.

43. Miscut 2 inch stock which does not fall below 1½ inch shall be admitted in No. 2 common, provided that the grade of such thin stock is in all other respects as good as No. 1 common.

44. In boards, fencing and dimension, stock falling below No. 2 grade and excluding dead culls shall be classed as No. 3.

45. Dressed timbers shall conform in grade to the specifications applying to rough timbers of similar size.

ROUGH YELLOW PINE—FLOORING STRIPS AND FINISHING.

46. Flooring strips are 3 inches, 4 inches, 5 inches and 6 inches wide when green; square-edged and evenly manufactured.

47. Finish must be evenly manufactured, and shall embrace all sizes from 1 inch to 2 inches thick by six inches and over in width.

48. No finishing lumber, unless otherwise ordered, should measure when dry and rough less than 1-16 inch scant in thick-

ness. No piece in any shipment of boards and strips shall be more than ¼ inch scant on 6 and 8 inch stock, 3-8 inch scant on 10 and ½ inch scant on 12 inch and wider stock.

49. Wane and seasoning checks that will dress out in working to standard thicknesses and widths are admissible.

50. Subject to the foregoing provisions rough finishing shall be graded according to the specifications applying to dress finishing. When like grade of both faces is required special contract should be made.

COMMON BOARDS, FENCING AND DIMENSION.

51. *Rough Common Boards and Fencing* must be evenly manufactured, and should not be less than ⅞ inch thick when dry, nor more than ½ inch scant of specified width.

52. *Rough 2 inch Common* shall be evenly manufactured and not less than 1⅞ inches thick when green, or 1¾ inches thick when dry. The several widths must not be less than ⅛ inch over the standard dressing width for such stock.

53. The defects admissible in rough stock shall be the same as those applying to dressed stock of like kind and grade, but such further defects as would disappear in dressing to standard size of such material shall be allowed.

54. Rough timbers 6x6 and larger shall not be more than ¼ inch scant when green and be evenly manufactured from sound stock with not less than three square edges, and must be free from knots that will materially weaken the piece.

55. Timbers 10x10 in size may have a 2 inch wane on one corner, or its equivalent on two or more corners, one-fourth the length of the piece. Other sizes may have proportionate defects.

56. Seasoning checks, and shakes extending not over one-eighth the length of the piece, are admissible.

**151. Standard Dimensions of the Southern Lumber Manufacturers' Association.**[1]

*Flooring.*—The standard of 1x4 and 6 inch shall be 27-32x 3¼ and 5¼ inches; 1¼ inch flooring, 1 3-32 inches.

*Ceiling.*—⅜ inch ceiling, 5-16 inch; ½ inch ceiling, 7-16 inch; ⅝ inch ceiling, 9-16 inch; ¾ inch ceiling, 11-16 inch; same width as flooring.

*Finishing.*—1 inch, S. 1 S. or S. 2 S., to 27-32; 1¼ inch, S. 1 S. or S. 2 S., to 1 3-32 inch; 1½ inch, S. 1 S. or S. 2 S., to 1 11-32 inches; 2 inch, S. 1 S. or S. 2 S., to 1¾ inches.

*Boards and Fencing.*—1 inch, S. 1 S. or S. 2 S., to 13-16.

[1] These particular dimensions cannot be assumed to hold for all parts of the country.

*Dimension.*—2x4, S. 1 S. 1 E., to 1⅝x3⅝ inches; 2x6, S. 1 S. 1 E., to 1⅝x5⅝ inches; 2x8, S. 1 S. 1 E., 1⅝x7½ inches; 2x10, S. 1 S. 1 E., to 1⅝x9½ inches; 2x12, S. 1 S. 1 E., to 1⅝x11½ inches; 4x4, ⅜ inch off side and edge; 4x4, S. 4 S., ¼ inch off each side.

**152. Rules Governing the Inspection and Measurement of Lumber in the St. Louis Market.**

RULE 1. Standard grades of lumber shall be firsts and seconds, common, and cull. In the grade of firsts and seconds the purchaser is entitled to a fair proportion of clear lumber, which must not be less than 33 1-3 per cent. First and clear are interchangeable terms meaning that the lumber must be 6 inches wide and over, except poplar, yellow pine and cypress, which must be 8 inches wide and over, and free from all defects.

RULE 2. Standard lengths shall be 10, 12, 14 and 16 feet. The first and second grade will admit nothing under 10 feet and not to exceed 10 per cent. of 10 feet in any lot; *i. e.*, 10 per cent. of all 10-foot lumber in any lot may be graded as firsts and seconds. In black walnut, cherry and hickory an exception is made, and the total amount of 10-foot lumber may be graded as firsts and seconds. An exception is also made in ash, in which 18 feet or longer, and in quarter-sawed lumber 10 per cent. of the entire lot may be graded as firsts and seconds. Shorter and longer than standard lengths in all varieties of hardwood lumber are to be reduced in grade unless otherwise agreed between buyer and seller, in which case it shall be so stated in the certificate of inspection.

RULE 3. Standard thicknesses shall be 1, 1¼, 1½, 2, 2½, 3, 3½ and 4 inches, except poplar, which will allow ½, ⅝ and ¾ inches in car lots.

RULE 4. Standard knots shall not exceed 1¼ inches in diameter and must be of sound character.

RULE 5. Lumber must be sawed into plump and even thicknesses. Scant-sawed lumber must be reduced to the next standard thickness, and in case of 1-inch lumber to one grade lower. All badly sawn, miscut, and uneven lumber shall be classed as cull, except when such will dress to its full length and width.

in the next standard thickness, in which case the piece shall not be reduced in grade.

RULE 6. Splits are always more or less damage to a piece of lumber. An allowance must be made in determining the quality or quantity, according to the nature of the split. A straight split extending not to exceed the width of the board in length shall be admitted into the grade of firsts and seconds.

RULE 7. A cull which will not work one-half its size without waste is a mill cull of no recognized value.

RULE 8. Lumber sawed for specific purposes, such as axles, bolsters, tongues, reaches, newels, balusters, squares, etc., must be inspected with a view to the adaptability of the piece for the intended use, as in many cases it can not be used for other purposes.

RULE 9. Merchantable lumber is lumber measured for what it will work.

RULE 10. Log run is the entire cut of the log, mill culls out.

RULE 11. It is important that all lumber shall be parallel in width, square-edged and with square ends.

Tapering lumber shall be measured one-third the length from the small end.

RULE 12. Ordinary season checks are not considered defects. Black stain, heart shakes, rots, wormholes and dote are considered serious defects, reducing to a grade lower than firsts and seconds.

RULE 13. The inspection grades of wagon stock, newels, balusters and table-legs shall be good and cull.

RULE 14. Newels from all kinds of timber must be clear and free from heart, to square 5, 6, 7, 8, 9 and 10 inches plump. The lengths must be 4 feet full, or multiples thereof.

RULE 15. Balusters and table-legs shall be clear and square 2x2, 2½x2½, 3x3 and 4x4, 30 and 32 inches long.

RULE 16. Bolsters must be 4 feet and 4 feet 6 inches in length, and the size must be 3x4, 3½x4½, 4x5, 4½x5½ and 5x6.

RULE 17. Reaches must be 2x4, 8, 9 and 10 feet, or 2¼x4½, 12 and 16 feet long.

RULE 18. Hickory axles shall be 6 feet for 3x4, 3¼x4¼, 3½x4½ and 4x5 inches and 6½ feet long, for 5x6 and 5x7.

RULE 19. Wagon tongues must be straight and 2x4 at the small end, and 3x4, 3½x4, or 4x4 at butt end, 12 feet long.

### POPLAR.

The inspection grades shall consist of *firsts* and *seconds, common* and *cull.*

*Firsts and Seconds* shall be 8 inches wide and over; at 8 inches will admit of 1 inch of bright sap, but no other defects; at 10 to 12 inches will admit of 3 inches of bright sap, or two standard knots; at 12 to 15 inches will admit of 4 inches of bright sap and two standard knots, or three standard knots if there is no sap.

Boards and plank free from other defects may be one-half bright sap if over 12 inches wide.

*Common* shall include any width not less than 6 inches, and will allow of bright or discolored sap and knots beyond those described in firsts and seconds. Two unsound standard knots will be allowed in this grade if over 12 inches wide, and splits shall not be considered a defect. Otherwise the lumber must be sound.

*Culls* shall comprise all widths and sizes having more defects than described in common, whether in the number or in the character of the knots, badly checked, and generally such lumber as is unfit for ordinary purposes.

*Box boards* shall be 12, 14 and 16 feet long, from 13 to 17 inches wide, free from all defects except bright sap.

*Poplar* strips shall be full 6 inches wide, 1, 1¼ and 1½ inches thick, 12, 14 and 16 feet long. Clear shall be free from all defects. Second clear may be one-half bright sap on one side and have one sound knot not over ¾ of an inch in diameter. Common shall embrace all sound strips with more defects than second clear. Cull shall contain all unsound strips that will work one-half its contents, and all tapering strips.

*Poplar squares* shall be graded No. 1, No. 2 and culls.

No. 1. Lengths may be 8, 9, 10, 12, 14, 16 and 18 feet. 4x4 will admit one-half inch bright sap, or two standard knots. 5x5, 6x6 and 7x7 will admit one-third bright sap or two standard knots. 8x8, 10x10 and 12x12 will admit one-half bright sap and three standard knots.

No. 2 will admit colored sap knots of a sound character, wane, ordinary season checks and splits not to exceed 12 inches in length.

*Cull* shall comprise all squares below the grade of No. 2.

### ASH.

*Firsts and Seconds* must be 6 inches wide and over. At 8 inches one and at 10 inches two standard knots, or their equivalent in other defects may be allowed. An allowance for more defects of this character may be made in proportion to increased width. Eighteen feet or longer must be 5 inches or over wide.

*Common* shall include 5 inches and over wide. At 6 inches one, and at 8 inches two standard knots, or their equivalent in other defects, may be allowed. An allowance for more defects of this character may be made in proportion to increased width.

*Cull* shall comprise all widths and sizes below the description of common.

### OAK.

*Firsts and Seconds* must be 6 inches wide and over. At 8 inches one, and at 10 inches two standard knots, or their equivalent in other defects, may be allowed. An allowance for more defects of this character may be made in proportion to increased width.

*Common* shall include 5 inches and over wide. At 6 inches one, and at 8 inches two standard knots, or their equivalent in other defects, may be allowed. An allowance for more defects of this character may be made in proportion to increased width.

*Dimensions* may contain sound hearts if well boxed. Heart shakes, rot and dote are not admissible.

*Cull* shall comprise all widths and sizes below the description of common.

### YELLOW PINE.

#### Finishing 1 to 2 inches.

The inspection grades shall consist of *firsts* and *seconds, common* and *cull,* and shall be inspected on best face.

*Firsts and Seconds* must be 8 inches wide and over; up to and including 10 inches wide will admit two sound knots not over ¾ of an inch in diameter; at 12 inches will admit three sound knots not over ¾ of an inch in diameter, or one standard knot. An allowance for more defects of this character may be made for increased widths. Bright sap is not considered a defect.

*Common* shall include all lumber not up to the grade of firsts and seconds, but free from shakes, large knots or unsound lumber.

*Culls* shall comprise all lumber below the description of common.

*Strips* shall be 4 inches and 6 inches wide.

*Firsts and Seconds* must be free from all defects on one side. Bright sap is no defect.

*Common* may have three small knots not more than ¾ of an inch in diameter, or one standard knot, blued sap or small wane on one edge which will not injure it for working to its full size.

*Culls* shall comprise all lumber below the description of common.

QUARTER-SAWED HARDWOOD LUMBER—OAK, SYCAMORE, ETC.

*Firsts and Seconds* must be 6 inches wide and over. At 7 inches one, and at 9 inches or wider two standard knots will be allowed.

*Common* shall be 3 inches and over wide. At 6 inches one, and at 8 inches two standard knots, or their equivalent in other defects, will be allowed. An allowance for more defects of this character may be made in proportion to increased width.

*Culls* shall comprise all lumber below the description of common.

QUARTER-SAWED OAK STRIPS.

Quarter-sawed oak strips shall be 3, 4 and 5 inches wide, and the inspection grades shall be *firsts* and *seconds* and *cull.*

*Firsts and Seconds* shall have one face clear of all defects.

*Cull* shall include all lumber not up to the grades of firsts and seconds.

BLACK WALNUT, CHERRY, BUTTERNUT AND CHESTNUT.

*Firsts and Seconds* must be 6 inches and over wide. At 8 inches one inch of sap or one standard knot, and at 10 inches two inches of sap or two standard knots may be allowed. An allowance for more defects of this character may be made in proportion to increased width.

*Common* shall be 5 inches and over wide and shall include all lumber not up to the grades of firsts and seconds, but available fully ¾ its size without waste, free from hearts and unsound lumber. Heart shakes, rot, dote or worm-holes are not admissible.

*Culls* shall comprise all lumber below the description of common.

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NOTE.—Gum spots are considered a serious defect, and when their damage exceeds one-sixth of the size of the piece, shall reduce the grade to common. When their damage exceeds one-third the size of the piece, it shall be reduced to cull.

### CYPRESS.

*Firsts and Seconds* must be 8 inches and over wide, and clear up to 10 inches; at 10 to 12 inches may have two standard knots and 3 inches of bright sap. An allowance for more defects of this character may be made in proportion to increased width. Free from other defects may be one-half bright sap. Lengths of 18 feet and over are allowed in this grade.

*Common* will contain all lumber under second class, and all shaky lumber that is available three-fourths.

*Culls* shall comprise all lumber below the description of common.

### GUM.

*Firsts and Seconds* must be 6 inches wide and over. At 8 inches may have one standard knot, and at 10 inches two standard knots; 10 to 12 inches may have three standard knots. An allowance may be be made for more defects of this character in proportion to increased width. Sap not admitted in this grade.

*Common* shall include all lumber available for use full three-fourths its size without waste, free from hearts and unsound lumber. Bright or slightly discolored sap may be included in this grade.

*Culls* shall comprise all widths and sizes below the description of common.

### BIRCH.

*Firsts and Seconds* must be 6 inches wide and over. At 8 inches one, and at 10 inches two standard knots, or their equivalent in other defects, may be allowed. An allowance for other defects of this character may be made in proportion to increased widths. Seventy-five per cent. of the face must be red.

*Common* shall be sound 5 inches and over in width, and may have defects not injuring it for ordinary use without waste. At 6 inches one, and at 8 inches two standard knots, or their equivalent in other defects, may be allowed. An allowance for more defects of this character may be made in proportion to increased width.

*Culls* shall comprise all widths and sizes below the description of common.

### HICKORY, PECAN, HARD AND SOFT MAPLE, ELM, BEECH AND SYCAMORE.

To these the standard rules governing Ash are applicable.

RULE FOR MEASURING LOGS.

All logs measured by the authority of this exchange shall be measured by Scribner-Doyle's Rule, as published in Scribner's Lumber and Log Book.

**153. Specification for Thoroughly Seasoned Lumber.** There is no difference between "seasoned" lumber and "dried" lumber. "Thoroughly seasoned" or "thoroughly dried" lumber is lumber which has been dried, either in the open air or in a dry kiln, until it has reached that state of dryness which is relatively permanent. It then contains water equal to about ten per cent. of its weight. This is what might be called the atmospheric moisture. This will remain in the wood unless driven off by evaporation at a temperature of 212 degrees Fahrenheit or more. The word "thoroughly" when used in this connection, means "uniformly" as well as "effectually." That is, "thoroughly dried" lumber is dried uniformly throughout its entire cross-section and throughout its entire length.

To determine the percentage of moisture of lumber it is only necessary to cut a section from a board or stick and weigh it; then dry in an ordinary stove oven with a slow fire for an hour or two and then weigh again; the difference in weight divided by the dry weight is the percentage of moisture. As determined by this test, "thoroughly dry lumber" should not contain more than ten or twelve per cent. of water, and the interior should be as dry as the exterior.

The necessity for using thoroughly dried lumber where shrinkage is to be avoided, arises from the fact that *below about 30 per cent. moisture lumber shrinks nearly as much as it dries.* That is to say, when lumber dries down from 30 per cent. moisture to 10 per cent. moisture it dries out, or loses in weight, 20 per cent. of its dry weight. It also loses about 20 per cent. of its dry volume, or say 15 per cent. of its volume at 30 per cent. moisture. The shrinkage lengthwise is very slight, hence it has lost about 15 per cent. of its cross-section, or say six or seven per cent. of each of its lateral dimensions. That is to say a board one foot wide at 30 per cent. moisture is only about 11⅜ inches wide at 10 per cent. moisture; or a flooring board

4 inches wide at 20 per cent. moisture is only about 3¾ inches wide at 10 per cent. moisture. On account of the very large radial fibres (medullary rays) in oak wood, this kind of lumber shrinks mostly in a circumferential direction, and all timber shrinks more circumferentially than radially since all woods have these medullary rays to a greater or less extent. It is for this reason that "quarter sawed" (radial sawed) lumber is more satisfactory than "flat sawed" for all kinds of furniture and house trimmings. For flooring quarter sawed, or "rift sawed" boards, presenting an "edge-grain" surface, is far preferable to "flat-grain" because it wears evenly and does not sliver on the surface.

The specification may read as follows:

All the lumber delivered under this contract, to be used for purposes of ——, shall be thoroughly seasoned or dried, either in the open air or in a kiln or both. By "thoroughly seasoned" as here used is meant a seasoning or drying uniformly throughout the entire sections of the various sizes delivered, and the average percentage of moisture contained in the lumber when delivered shall not be more than ten per cent. of its weight, as determined by actual experiment.

154. **Specification for Cast Iron.**[1] There is probably no material in engineering structures which can more profitably be governed by specifications involving tests than cast iron. Since cast iron usually breaks under some kind of shock or blow, it is more necessary to test the iron for resilience than for strength. The most convenient test for resilience is the cross-bending test, in which deflection is measured. The half product of the deflection multiplied by the breaking load is the mathematical measure of the resilience in inch pounds. This can be reduced to an absolute unit by dividing by either the weight or the volume of the bar, and if all the bars tested in this way are rectangular in cross-section and of uniform size from end to end, the unit obtained in the above manner will be comparable, notwithstanding great variations in the dimen-

[1] See the author's *Materials of Construction* for a full description of methods of manufacture, methods of testing and physical properties of all the metals commonly used in engineering works.

sions. It is best, however, to have the test specimens always made from the same pattern, using the thickness of metal which corresponds closely to the average thickness of web of the castings required. If uniform test specimens be employed, there is no necessity of dividing the half product of deflection and breaking load by the volume or by the weight, since this volume or weight remains a constant. In this case the relative resilience of the material will be indicated by the product of the breaking load into the maximum deflection. The *strength* of the material will be indicated by the breaking load alone.

The following specification is the one commonly employed for all castings made for the water department of St. Louis, and is designed to answer the above requirements.

CAST IRON.

All of the iron castings shall be made from a superior quality or iron, remelted in the cupola or air furnace, tough and of even grain, and shall possess a tensile strength of not less than 18,000 pounds per square inch.

Test bars of the metal 3 inches by ½ inch, when broken transversely, 18 inches between supports, and loaded in the center, shall have a breaking load of not less than 1,000 pounds and shall have a total deflection of not less than 3-10 of an inch before breaking.[1] Said bars to be cast as near as possible to the above dimensions without finishing; but correction will be made by the water commissioner for variations in thickness and width, and the corrected result must conform to above requirements.

Specimen bars of the metal used, of a size and form suitable for testing, shall be prepared when required.

These specimen bars shall be poured from the ladle at any time, either before or after the casting has been poured, as may be required, and shall present a true specimen of the iron used for making the castings.

If any two test bars cast the same day show a breaking strength of less than 18,000 pounds per square inch, or do not show the required cross-breaking load and deflection, all the castings made from the same mixture to be rejected.

All castings shall conform to the shape and dimensions required by the drawings, and shall be clean and perfect, with-

[1] The tensile strength may be raised to 20,000 or even to 25,000 pounds per square inch, while the deflection may be made ⅜ inch for ordinary good cast iron and ½ inch for a better quality. For a superior quality it may be made ⅝ inch, with a breaking load of 1,250 pounds.

out blow or sand holes, or defects of any kind. No plugging or other stopping of holes will be allowed.

Particular care shall be taken to secure perfect lugs, where such are required by the drawings. Whenever any doubt exists of the exact interpretation as to the shape or dimensions shown on the drawings, the contractor must consult with the water commissioner, or his duly authorized agent, in regard thereto.

M. L. H.

**155. Specification for Cast-Iron Water Pipe.** The following specifications for cast-iron water pipe were used in the contract of the new water works system of Cincinnati (1900–1902). Special attention is called to provisions Nos. 14 and 15. It is well known that the coal-tar coated cast-iron water pipe will rust more or less on the outside and will form numerous "tubercles" of iron rust upon the interior. This rusting action is certainly due to imperfect coating and this in turn is doubtless due to the iron scale and other foreign matter left on the outside of the casting when dipped into the bath of coal-tar varnish. It is now well known that no perfect protection of iron by painting when exposed to the weather, is effective unless the iron has first been entirely freed from rust and the ordinary oxide coating which it has when it comes from the rolls. The sand blast is the only perfect means of cleaning the iron from this oxidized coating. This sand blast method of cleaning water pipes is provided as an alternative by provision 14 below, and was, with much difficulty, forced upon the contractors. The author believes this to be the only absolute assurance against exterior rusting and the forming of tubercles upon the interior of cast-iron water pipe. Methods can be devised for applying this method of cleaning to the interior as well as to the exterior of such pipes. This would not only greatly extend the life of the pipe but it would preserve its original efficiency as a water carrier. The cost of this method of cleaning the pipes would be a very small percentage of the total cost of the works but would add largely to the life and efficiency of that part of the system which represents three-fourths of the total cost.

1. The iron shall be of pig metal, properly selected and compounded to obtain the desired quality. It shall be a tough,

gray metal; close, even grained; uniform in quality; soft enough to permit drilling and cutting, and capable of showing indentations from a sharp blow of a hammer without flaking. When tested in specimens one inch in diameter, from which the skin has been removed by turning, all metal used shall stand, without breaking, a tensile stress of not less than 20,000 pounds per square inch. Cast bars, one inch square, resting horizontally on supports four feet six inches apart, shall stand, without breaking, a weight of 550 pounds suspended at the center.[1] In casting pipe 30 inches and above in diameter the metal shall be poured twice in order to secure a thorough mixture.

2. All straight pipes shall be cast vertically, in dry sand molds and loam cores, with socket-end down.

3. All pipes and special castings shall be cooled gradually to avoid chilling or unequal contraction in any part.

4. All pipes and special castings shall be cast with sockets and spigots, or with flanges, as specified or ordered.

5. All socket-and-spigot pipes and special castings shall be square at the ends and at the inner edge of sockets, and of the exact internal diameter and dimensions specified. Their sections shall be truly circular and concentric, and their thickness uniform throughout their length between socket and spigot. They shall be free from cracks, cinders, scoria, blisters, air and sand holes, cold-shuts, and all other imperfections. They shall have a smooth surface inside and outside. All inside projections must be carefully removed and made even and smooth throughout. No plugging of holes or flaws will be allowed. All spigot-ends shall fit well into sockets to the bottom, without requiring chipping in the field.

6. The weight of the straight pipes, their joint room, length and thickness shall be as follows:

| Interior Diameter, Inches. | Weight in Pounds. | Hyd. Test Pressure in lbs. per sq inch | Thickness of Joint Room | Total Length. | Thickness in Inches. |
|---|---|---|---|---|---|
| 4 | 298 | 300 | 3/8 | 12′ 4″ | 1/2 |
| 6 | 480 | 300 | 3/8 | 12′ 4″ | 9-16 |
| 8 | 695 | 300 | 3/8 | 12′ 4″ | 5/8 |
| 12 | 1,011 | 300 | 3/8 | 12′ 4″ | 5/8 |
| 24 | 2,753 | 250 | 3/8 | 12′ 4″ | 7/8 |
| 30 | 3,765 | 250 | 1/2 | 12′ 4 1/8″ | 15-16 |
| 36 | 5,018 | 250 | 1/2 | 12′ 4 1/8″ | 1 1-16 |
| 48 | 8,676 | 200 | 1/2 | 12′ 5″ | 1 3/8 |
| 60 | 12,768 | 200 | 1/2 | 12′ 5″ | 1 5/8 |
| 72 | 17,628 | 200 | 1/2 | 12′ 5″ | 1 7/8 |

[1] The deflection of this bar should also be specified as not less than one inch, in order to obtain a measure of its resilience. See Article 154. J. B. J.

7. The joint rooms shall not vary more than one-sixteenth of an inch, and the lengths shall not differ from the above except by written consent of the chief engineer, in which case the weights as above given shall be modified in accordance therewith.

8. No pipe whose thickness of metal is more than one-sixteenth of an inch less than above specified shall be received.

9. Straight pipes weighing less than 97½ per cent. of the above specified weights shall be rejected. Any excess of weight of more than 2½ per cent. in individual pipes shall not be paid for. Special castings weighing less than 97 per cent. of the standard calculated weight shall be rejected. Any excess of weight of special castings of more than 4 per cent. shall not be paid for.

10. The sockets and spigots shall conform in shape and size; and the curved pipes, branches, crosses, and other special castings shall be made in conformity with the drawings furnished and approved by the chief engineer.

11. Lugs shall be cast on all such pipes and special castings as may be directed by the chief engineer. The sockets and spigots shall be tested by suitable gauges, and the thickness of the metal shall be tested by calipers.

12. Flanged pipes shall be cast vertically in dry sand molds and loam cores in a manner similar to the socket-and-spigot pipe. All flanges shall be smooth, sound and free from all imperfections; to accomplish which the upper flange shall be cast with a suitable sinking head thereupon, which shall afterwards be cut off. Before coating the pipes the flanges shall be faced in the lathe at right angles with the axis of the pipes and drilled by template for bolt connections, as shown on the drawings.

13. Every pipe and special casting shall have cast upon it, in letters and figures two inches long and ⅛ inch in relief:

(1) The maker's name or initial.

(2) The year in which the casting was made.

(3) The running number of each successive casting made of the different kinds and sizes required. The serial number of rejected pipes or specials shall not be duplicated.

14. The pipes and special castings shall be free from rust, and shall be carefully cleaned with both hard and soft brushes, to remove all adhering sand, clay and dust, or the exterior and interior surface of the pipes and special castings shall be thoroughly cleaned by the use of the sand blast if elected by the trustees. Both the inside and outside surfaces of the pipes must be smooth before and after dipping.

15. After the pipes and special castings have been cleaned to the satisfaction of the chief engineer, they shall be subjected to a careful and thorough hammer inspection, after which they

shall be thoroughly dried and uniformly heated in suitable ovens to a temperature of 300 degrees Fahr., and then dipped vertically in a bath of coal-tar varnish composed of 5 per cent. of resin and 95 per cent. of the best coal tar, distilled at a temperature of 440 degrees Fahr., evaporating all the lighter oils and retaining the heavy oils. Each pipe shall be heated to a temperature of 300 degrees Fahr., and shall at that temperature be dipped into the coal-tar varnish, which shall be maintained at a uniform temperature of 280 degrees Fahr., while the pipe is immersed. The pipe shall remain in the varnish at least ten minutes; then withdrawn, drained, and quickly dipped a second time to insure the coating of all parts which may have remained uncoated. The dipping material must be kept free from sand, grit, or other foreign material. The uniformity of the composition must be maintained by adding fresh materials; and as often as may be necessary, in the opinion of the chief engineer, the tank shall be emptied and refilled with clean and pure material. The coating must be adhesive, continuous, smooth, hard, yet tough, tenacious, and durable. It must be free from blisters and bubbles.

16. After being coated, every pipe and casting shall be drained of the surplus varnish, and when dry shall be tested, at the expense of the contractor, under such hydrostatic pressure as is specified for each size of pipe in paragraph 6 of these specifications.

17. After having been coated and tested, every pipe and special casting shall be carefully weighed under the supervision of the chief engineer, and the weight and class thereof, as well as the inspector's initials, shall be marked thereon in plain, legible letters and figures, in white paint, inside and outside.

18. An inspector appointed by the board of trustees, "commissioners of waterworks," shall, under instructions and direction of the chief engineer, inspect and supervise the work and material, and see that all the stipulations of the specifications are faithfuly carried out. He shall have unrestricted access to all parts of the works. All tests and weighing shall be made under his personal supervision, and the contractor shall furnish him with all facilities, and with all tools, specimens, appliances and labor necessary for this work without charge.

19. A final inspection may be made after the pipes or special castings have been delivered, and any pipe or casting found defective at any time after acceptance by the inspector, and at the time of unloading on the waterworks grounds, shall be rejected, and the contractor shall replace them with good pipes and special castings acceptable to the chief engineer free of cost to the board of trustees, "commissioners of waterworks."

20. All scales used for weighing and all gauges used in test-

ing shall, whenever required by the inspector, be tested by proper authorities with standard United States weights and gauges.

21. All pipes and castings shall be delivered on board cars on the side track to be built on the waterworks grounds near California, Ohio, and connecting with the Cincinnati, Georgetown & Portsmouth Railroad.

22. All pipes and special castings shall be delivered in all respects sound and conformably with the specifications. In handling or transporting the pipes or special castings, care must be taken not to injure the coating in any manner, nor shall any pipes or other material be placed inside of any pipes or special castings after they have been coated.

23. The prices paid for the pipes and special castings shall include all the materials, patterns, labor, freight charges, the cost of testing, facing, drilling, coating, weighing and marking, and other expenses necessary or incidental to the manufacture and delivery of said pipes and castings on board cars on the waterworks grounds near California, Ohio, excepting the salary of the inspectors appointed by the trustees. The ton shall be the net ton of 2,000 pounds.

24. The prices paid for straight pipe shall include straight pipes of all lengths not exceeding 12 feet and not less than 6 feet. Straight pipes with socket or spigot at one end and flange at the other end shall be paid for as flanged pipes.

25. Special castings with socket or spigot at one end and with flange at the other end shall be paid for as flanged specials.

G. H. B.

**156. Specifications for Riveted Steel Water Pipe.** The following specifications were used for the riveted steel conduit of the city water supply of Cambridge, Massachusetts.[1] There is no question but that rivet heads and the lapping of the sheets at the transverse joints greatly retard the flow of the water and consume a large portion of the hydraulic head. This might be avoided by counter-sinking the rivets (if the metal be thick enough) and by using an outside buttstrap connection at the transverse joints. The author suggests these changes in the following specification:

*Metal.*—The steel for the plates used in the manufacture of the pipe to be of class termed soft, and shall be made by the open hearth process. It shall contain not more than 0.06 per

[1] See a paper by the author of these specifications on "The Use of Steel for Water Mains" in *Jour. N. E. Waterworks Association*, Vol. XIII.

cent. of phosporus, 0.06 per cent. of sulphur, and 0.60 per cent. of manganese.

The steel must also stand the following physical tests:

Tensile strength to be not less than 55,000 pounds nor more than 65,000 pounds per square inch.

Elastic limit to be not less than 30,000 pounds per square inch.

Elongation to be not less than 22½ per cent. longitudinally and 20 per cent. transversely of the plates.

Tensile test specimens to be 8 inches long and 1½ inches wide between measuring points.

Bending test specimens cut lengthwise or crosswise from the sheet to be six (6) inches long and one (1) inch wide, to be bent 180 degrees upon itself when cold, and hammered down flat, without sign of fracture on the outside of the bent portion.

Punching test specimens to be one and three-fourths (1¾) inches wide and not less than ten (10) inches long, in the middle of which a row of not less than eight (8) holes three-fourths (¾) inch diameter spaced one and one-fourth (1¼) inches between centers shall be punched without causing any cracks.

Drifting test specimens to be three (3) inches wide and not less than five (5) inches long, in which not less than two (2) holes three-fourths (¾) inch diameter, spaced two (2) inches between center and one and one-half (1½) inches from the edges, shall be punched and then enlarged by blows from a sledge hammer upon a drifting pin until said holes are at least one and one-fourth (1¼) inches in diameter, without causing any cracks; such enlargement to be done cold.

The plates shall be free from lamination and surface defects, and be fully up to the required gauge for thickness on the edges. Any plate whose thickness at any point may be found less than ninety-five (95) per cent. of the required thickness, shall be rejected without appeal; furthermore, at least ninety (90) per cent. of the plates must be of the required thickness at all points.

Rivet steel shall be soft and have a tensile strength between the limits of 50,000 and 58,000 pounds per square inch, with an elastic limit of not less than 30,000 pounds per square inch, and with an elongation of not less than 28 per cent. in a test bar eight inches long between measuring points and full diameter of rivet, and with a reduction of cross sectional area at the point of fracture of not less than 50 per cent.

The material shall also be of such quality as will stand bending double and flat before and after heating to a light yellow heat, and quenching in cold water, without sign of fracture on the convex surface of the bend. The quality of material of

rivet rods and subsequent manufacture into rivets shall be such that the edges of heads of properly heated and driven rivets shall be free from checks or cracks. All steel rivets not conforming to the above requirements will be rejected.

All plates and rivets must be free from rust and be kept under cover, from the time of manufacture of the plates until the completed pipe is dipped or coated. In case of accidental rusting, the rust must be removed from the plates in the manner hereinafter specified before proceeding with the manufacture of the pipe.

*Manufacture of Pipe.*—The sheets or plates must be of such dimensions as to admit of being rolled into true cylinders not less than seven (7) feet in length and of the required internal diameters, with ample allowance for the necessary overlap at the single longitudinal seam of each such cylinder. One-half of the whole number of sheets will be formed into "inside courses," or cylinders, having the specified internal diameter of the conduit pipe, and the remaining half into "outside courses," or cylinders, whose internal diameter shall be exactly equal to the external diameter of the inside courses, said courses alternating and forming a tight fit with each other before any protective coating is applied to the metal.

The conduit pipe shall be forty (40) inches in internal diameter of the said inside courses. The thickness of the steel plates for the pipe with flanged ends to be placed within the reservoir is to be 1/4 inch. The thickness of the plates for the pipe at the crossings over the roadway and at the railroad will be 3/8 inches. The thickness of the plates for all the rest of the pipe will be 5-16 inches.

The edges of each plate must be properly planed or cut to true lines and beveled for caulking all around; and at the end of each course, when the lap of the longitudinal seam occurs, the plate must be reduced by cold hammering or planing, or both, to a fine edge, through which one of the rivets of the round seam must be driven to insure tightness. In addition to this rivet, still another rivet must be driven through the three thicknesses of plate at such joints. Each plate must be rolled to a perfect cylinder of the required diameter.

All rivet holes must be spaced with precision, and in punching the same, the punch shall be applied to the side of the plate which is to be placed in contact with another. In punching said holes, the best and sharpest dies and punches are to be used, and all burrs caused by the punch on the lower side of the plate shall be removed by counter-sinking.

All rivet holes are not to exceed the specified size of rivet by more than 1-16 of an inch, and are to be so punched that in assembling the several parts of a member together a rivet 1-16

inch less in diameter than the hole, can be entered hot into any hole without "drifting." Occasional variations must be corrected by reaming.

Whenever possible, rivets must be driven by machines capable of retaining the applied pressure after the upsetting is completed. Rivets when driven must completely fill the hole and have full round heads, concentric to the rivet hole, and thoroughly pinch the connected members together.

All loose or imperfectly driven rivets must be replaced by sound and perfect fitting ones.

At each junction of the straight seam and the round seam where three thicknesses of plate come together, and in all places where castings of any description are to be attached to the pipe, special rivets of extra length must be provided and driven.

The rivets used for attaching castings of any description to the pipes and connecting together plates or courses in the field, or by hand-work in the shop, shall in all cases be of the best quality of wrought iron, and be driven in the best and most workmanlike manner in every respect. All provisions herein contained, relating to riveting done in the shop, shall also apply, as far as practicable, to rivets driven in the field, or along the line of the conduit.

All circular seams to be single riveted, and the longitudinal seams to be double riveted, except where shown otherwise on detail plans.

The pipe is to be manufactured in lengths of four or more courses each, the outside and inside courses alternating with each other, so that each length will have an outside course on one end and an inside course on the other end; also in such manner that the longitudinal seams will alternate to the right and left not more than one foot from the centre line of the pipe.

Where angles or curves occur in either the alignment or the grade of the conduit, the plates must be cut and punched to the required lines for forming a small oblique angle at the round seams of as many courses as may be needed to produce the given total deflection or curvature in each locality, and the courses must be put together with the longitudinal seams alternating as aforesaid. In general, the deflection angle formed by two consecutive courses may range from one (1) to five (5) degrees in horizontal or vertical projection, according to the locality; but greater deflection angles may be made if ordered by the engineer.

Where ordered by the engineer the ends of the pipe to be provided with suitable flanged rings or collars of steel or iron, riveted to the pipe and drilled for bolting as shown on detail drawings.

Stiffening rings of suitable steel or iron shall be placed about the pipes and securely riveted to the same where ordered by the engineer. The price for furnishing and placing the flanges and rings to be paid for by the pound at the price stipulated in item (*q*), plan B.

Openings for the manholes, branches, blow-offs, air valves, etc., will be cut, and the cast iron fittings riveted on in the shop before the coating is applied.

All riveted seams and joints of every description shall be thoroughly caulked, both on the inside and the outside of the pipe, in the best and most workmanlike manner for first-class boiler work, while for the necessary distance from all laps the seams shall be both chipped and caulked. The caulking of all seams made in the shop must be done before the coating is applied to the pipe, and every precaution must be taken, both in the shop work and in the field work, to insure the utmost strength and tightness.

The cost of furnishing all appliances, materials and labor required for the manufacture of the pipe as aforesaid, except the castings and special fittings, must be included in the price bid per lineal foot for the conduit pipe laid in place complete, said price also to include the cost of riveting such castings and fittings to the pipe, the cost of making connection with the ends of the special sections and ends of the cast iron pipe at the engine house and at the reservoir, and all incidental work.

During its manufacture, sample lengths of pipe, to be selected by the engineer as frequently as he may deem necessary, shall be tested before or after coating under a water pressure equal to at least 100 pounds per square inch. All such tests will be made at the contractor's expense, and he shall furnish all the necessary appliances and labor for their performance to the engineer's satisfaction.

*Coating.*—After the pipes are manufactured and the openings required for connections, manholes, air valves, etc., cut in the appropriate sections, and the stiffening rings, collars, and fittings, riveted in place, they are to be covered with a protective coating of the material and in the manner recommended by Prof. A. H. Sabin, of Long Island City, of New York, or by some process equally satisfactory to the engineer.

If the process of Prof. Sabin is used, the pipe will be heated to above 212 deg. Fahrenheit. It will then be dipped in the coating compound manufactured by E. Smith & Co., of New York, which must be heated to above 250 deg. Fahrenheit. After draining, the pipe will then be placed and kept vertically in a suitable baking oven with a pan under each pipe to catch the drip.

The pipes must be kept in the oven at a heat of not less than

500 deg. Fahrenheit, for about four hours, until the coating has become hard; when cold, the pipes may then be removed from the oven and transported to the work.

The heads of all rivets driven after the coating has been applied, or any parts of the coating injured in shipment, must be thoroughly covered with "black bridge paint," manufactured by E. Smith & Co., of New York, and allowed to become sufficiently hard before being handled or covered up.

*Manholes.*—When directed by the engineer, the contractor shall furnish and put in place in the steel pipe conduit, manholes, with covers, gaskets and bolts complete. The openings for said manholes shall be elliptical, with clear major and minor diameters of not less than 16 and 14 inches respectively; and the joint between the frame and cover must in all cases be made by truly facing or milling the abutting surfaces and interposing a suitable gasket of sheet copper or lead. No portion of the frame or cover shall project within the cylindrical cross-section of the pipe, and the design of the manhole in all its details shall be subject to the approval of the engineer.

Payments for all manholes ordered and put in place in conformity with the engineer's directions, will be made at the price stipulated in item (*p*), plan B, but any manhole not so ordered and which is put in place by the contractor at any time for his own convenience during the construction of the conduit or for making any repairs thereto, and the replacement of gaskets in any manhole opened for any purpose by him, will be at the said contractor's expense.

*Transportation and Delivery.*—After the steel pipe is manufactured and coated as specified above, it is to be transported and delivered along the route of the pipe line, or on adjacent land, as directed by the engineer. Great care must be taken by the contractor in the transportation and delivery to prevent injury to the coating of the pipe and special fittings and castings, or deformation and damage to the pipe itself. All damage to the coating must be made good by the contractor by re-coating the damaged portions in a manner satisfactory to the engineer.

Any section of the pipe showing appreciable indentation or deformation may be rejected by the engineer.

The pipe is to be placed by the contractor in the trenches as prepared by the city, upon wooden blocks set by said city, and the sections of the pipe carefully riveted together. Rivets to be of same quality as those specified for shop riveting, and will be well and thoroughly driven by hand. After riveting, the joints must be thoroughly caulked.

The section of the pipe shall be so laid as to have the longitudinal seams on top. Rivet heads and all portions of the pipe coating injured in the laying shall be coated while in the trench

with the "black bridge paint," manufactured by E. Smith & Co., of New York, in a manner satisfactory to the engineer.

*Setting Valves.*—The city will furnish and deliver at the work the four sets of 30-in. valves and the cast iron connections; and the contractor is to connect the same with the flanged ends of the pipes, furnishing therefor all bolts, lead, labor, etc. The foundation and rests for the valves and special connecting pipes will be furnished and set by the city.

The sum to be paid for placing each set of 30-in. valves and connecting pipes, also placing the 30-in. valve and special castings at the cross-over near the Watertown Branch Railroad, and connecting with the ends of the 40-in. riveted steel pipe is specified in item (*n*), plan B.

Excavation of the trench, for the pipe-laying and making up the joints, will be done, also all cradles and bearing blocks will be furnished and set by the city, in advance of the work of placing the pipe. Any damage done to the trench or disarrangement to the blocks and bearing pieces after the same has been dug or set, must be made good by the contractor. The cost of connecting the steel pipe with the cast iron pipe at the engine house and also the gate house of the reservoir must be included in the price for the steel pipe.

The pipes and appurtenances must be kept well brushed out and thoroughly cleansed from all dirt or rubbish of any kind and the ends of the pipe and branches must be kept covered with suitable wooden caps.

*Testing Pipe.*—As soon as practicable after the pipe is laid and riveted in the trench the pipe will be tested, at the expense of the contractor, in convenient lengths of about 2,500 feet, to a pressure of 100 pounds per square inch. The contractor must furnish at his own expense such caps and plugs as may be necessary to close the open ends of the pipe. During this test all the joints shall be carefully examined and leaky joints caulked and made tight in a manner satisfactory to the engineer. The contractor to supply all needed water and appliances for testing at his own expense.

If, during the test, any pipe, special fitting or casting supplied by the contractor, should burst or be found defective in any respect for any cause, the same shall be removed and be replaced with a sound piece, and any damage to the trench or property resulting from said defect or failure must be made good by the contractor without extra compensation.

At the completion of the work the entire pipe line as laid will be inspected inside, and any material found therein must be removed by the contractor.

It is to be understood that all the necessary materials, tools, machinery, derricks, labor, etc., necessary for manufacture, de-

livery and placing of the pipes, and setting the gates and special castings, in the trench complete and ready for use, is to be furnished by the contractor.

The price to be paid per each lineal foot of 40-in. riveted steel conduit pipe furnished, manufactured, coated and placed in the trench and accepted by the engineer is specified in item (*h*), plan B.

*Riveted Pipe with Flanged Ends.*—The 40-in, riveted steel pipe with flanged ends will be made of sheets ¼ inch in thickness, of dimensions as shown in detail drawings, and made under the foregoing general specifications.

This pipe will not be placed in the reservoir by the contractor, but will be delivered on adjacent grounds as directed by the engineer.

The price to be paid for each lineal foot of 40-in. riveted steel pipe with flanged ends delivered on the ground, is specified in item (*i*), plan B.

The sum to be paid for each pound of wrought iron or steel collars, stiffening rings, etc., classed as "special fittings," furnished, and riveted to the pipe, as directed, is specified in item (*q*), plan B. L. M. H.

**157. Specification for Wooden Stave Pipe.** The following specification was prepared and used in California by one of the most experienced engineers in this kind of construction:

*Dimensions.*—The stave pipe built under these specifications shall have inside diameter as near as may be of 24 inches for the reservoir inlet pipe, and 18 inches for the independent connection between the outlet pipes and the Vermont avenue line; and shall consist of wooden staves, steel bolts, malleable cast saddles and metallic tongue.

*Staves.*—The staves shall be made of clear redwood, free from sap, which shall have been on sticks at least thirty days before being milled. The finished thickness shall not be less in either case than 1⅜ inches. The broad sides shall be dressed to conform to the outside and inside radii of the pipe. The edges shall be dressed to the radial planes, except that a slight bead shall run along on edge of each stave. The ends of the staves shall be accurately squared and shall be slotted for insertion of a No. 14 metallic tongue, so as to secure the same position for all staves. The staves may vary in length from 10 to 24 feet, but not more than 10 per cent. shall be less than 12 feet, and not more than 40 per cent. shall be less than 14 feet.

*Bands.*—The bands shall be homogeneous mild steel, having a tensile strength of from 58,000 to 65,000 pounds to the square inch, and the elastic limit shall not be less than 60 per cent. of the tensile strength. The elongation shall not be less than 24

per cent. in a test piece 8 inches long, and shall bend back upon itself cold without fracture. The section of the band shall be $\frac{3}{8}$ inch round. The thread shall be cold rolled, and shall be as strong as the body of the bolt. The washers shall be 0.11 inches thick, and the nuts shall run easily but not loosely on the thread.

*Saddles.*—The saddles shall be of best malleable cast iron of such shape as shall leave the entire band in a plane perpendicular to the axis of the pipe. The strength shall be in excess of the bands. They shall be free from defects and shall fit closely upon the outside of the pipe.

*Tongues.*—The tongues shall be $1\frac{1}{2}$ inches wide, and long enough to extend into the adjacent side staves when in place.

*Construction.*—The pipe when laid shall conform accurately to the stakes of the engineer. The staves shall break joints, and no joints in adjacent staves shall be nearer than 24 inches. The pipe when finished shall be round and smooth, both outside and in.

The bands shall be put on at right angles to the staves. The seam joints shall be made tight by frequent and thorough cinching of the bands. The butt joints shall be made tight by longitudinal driving of the staves, using wooden driving bars.

*Coating.*—The steel rods shall be coated with asphalt after the manner specified for the iron pipe. Any spots where the coating has become damaged, after the bands are placed in the pipe, shall be thoroughly painted over. The nuts, washers and shoes shall be similarly treated.

*Spacing.*—The band spacing shall be as given in the following table:

(The pressure to be the difference between the elevation of the bottom of pipe and 493.5 feet.)

| Diameter of Pipe | Pressure in Feet Head. | Distance C. to C of Bands |
|---|---|---|
| 18 inches | 25 to 30 | 9 inches |
| 18 inches | 30 to 35 | 8 inches |
| 18 inches | 35 to 40 | $7\frac{1}{2}$ inches |
| 18 inches | 40 to 45 | $7\frac{3}{8}$ inches |
| 24 inches | 25 to 30 | 8 inches |
| 24 inches | 30 to 35 | $7\frac{1}{4}$ inches |

*Backfilling.*—The contractor supplying the pipe shall also backfill the same to a depth of six inches over the top of the pipe; the material to be carefully tamped under and about the same.

*Connections.*—The pipe shall be connected up with the various specials as shown on the plan with oakum and lead joints.

A. L. A.

**158. Specifications for Wrought Iron Chains.** The following specifications for wrought iron chains are in use (1902) by the Pennsylvania Railroad Company. It will be noted that there is no specification concerning the material from which the chains are made, the tests of the completed chains being regarded as sufficient. Presumably to satisfy these requirements an excellent quality of wrought iron would be required.

All chain will be ordered subject to inspection and test by the company's inspectors before shipment. Manufacturers filling orders will, when they have a shipment of chain ready, so advise the general superintendent of motive power. They will be required to furnish suitable testing machines, and such assistance as will enable the inspectors to properly determine whether the chain meets the requirements, and must be prepared to ship in the presence of the inspectors.

All chain will be proof tested to the strains shown in the table below, which it must stand without deformation, and in addition one short length of not less than two (2) feet for each two hundred (200) feet presented, shall be tested to destruction, and the two hundred (200) feet will be rejected if the test length falls below the figures given for breaking weight and elongation. On orders calling for less than two hundred (200) feet, one length will be tested to destruction. When chain is ordered in lengths complete, with links, hooks, etc., welded on, as used on cars or for cranes, the long links, hooks and eye bolts must be included in the proof test, such lengths may be chained together by temporary shackles during the test. One per cent. of the chain thus presented for test must be measured and weighed to determine the weight per foot of chain, not including long links and hooks. If it should be impossible to determine weight of chain with long links and hooks attached, the long links must be cut and afterwards replaced in the presence of the inspector before shipment, but with care this cutting may generally be avoided.

All chain must be smooth, free from the appearance of burnt welds, cracks or overlaps, and must have a workmanlike finish. Any chain defective in these respects will be rejected. Chain must not be less than the nominal size in the body or welds. Any chain found defective after shipment, will be returned without freight charges. Chain weighing in excess of the limits of weight shown in the table below, will be paid for at that weight.

The company's drawing of "Standard Chain Links" No. 13,124 and detail drawings of "Standard Chains" will form part of these specifications. Drawing No. 13,124 gives the de-

sired dimensions of links, and if the length of 100 links in any of the crane chains is greater than shown, by as much as one per cent., the same will be rejected. In the case of the 5-32 inch and 3-16 inch chains, as much as ten per cent. excess length of link will be allowed. For the remaining chains this limit will be two per cent. To determine the length, a piece of chain containing 100 links whenever practicable will be selected, and the distance from inside end to inside end of end links measured, this measurement will be taken while the chain is in test machine for proof test, with no more than ten (10) per cent. of the proof load on to take up the slack. If the length of chains ordered will not contain 100 links, then 50, 25 or 10 links may be measured. The highest practicable number should however always be selected.

The main requirements of the specifications are given in the following table:

| Number on Drawing. | Nominal Diameter of Wire Inches. | Description. | Specifications. | | | | |
|---|---|---|---|---|---|---|---|
| | | | Maximum Length of 100 Links. Inches | Weight Per Foot. Pounds | Proof Test. Pounds. | Breaking Weight. Pounds. | Elongation Per cent. |
| 1 | 5-32 | Twisted Chain..... ........ | 103.1 | 0.20 | ........ | ...... | ...... |
| 2 | 3-16 | Twisted Chain ... . | 96.2 | 0.35 | ........ | ...... | ...... |
| 2½ | 3-16 | Perfection Twisted Chain .... | 151.25 | 0.266 | ........ | ...... | ...... |
| 3 | ¼ | Straight Link Chain ...... | 102.0 | 0.70 | 1,500 | 3,000 | 10 |
| 4 | 5-16 | Straight Link Chain......... . | 114.7 | 1.10 | 3,000 | 5,500 | 10 |
| 5 | ⅜ | Straight Link Chain.......... . | 114.7 | 1.50 | 3,500 | 7,000 | 10 |
| 6 | ⅜ | Crane Chain . .. ....... .. . | 113.6 | 1.50 | 4,000 | 7,500 | 10 |
| 7 | 7-16 | Straight Link Chain ....... .. | 127.5 | 1.90 | 5,000 | 9,500 | 10 |
| 8 | 7-16 | Crane Chain ... .. . | 126.3 | 1.90 | 5,500 | 10,000 | 10 |
| 9 | ½ | Straight Link Chain........... | 153.0 | 2.50 | 7,000 | 12,500 | 10 |
| 10 | ½ | Crane Chain .. ........ .. | 138.9 | 2.50 | 7,500 | 13,000 | 10 |
| 11 | ⅝ | Straight Link Chain........... | 178.5 | 4.00 | 11,000 | 20,000 | 10 |
| 12 | ⅝ | Crane Chain..... . ....... .... | 176.7 | 4.00 | 11,000 | 20,000 | 10 |
| 13 | ¾ | Straight Link Chain.... ....... | 204.0 | 5.50 | 16,000 | 29,000 | 10 |
| 14 | ¾ | Crane Chain...... . .......... | 202.0 | 5.50 | 16,000 | 29,000 | 10 |
| 15 | ⅞ | Crane Chain ... ........... | 252.5 | 7.40 | 22,000 | 40,000 | 10 |
| 16 | 1 | Crane Chain...... ............ | 277.7 | 9.50 | 30,000 | 55,000 | 10 |
| 17 | 1⅛ | Crane Chain .... ........ . . | 303.0 | 12.00 | 40,000 | 66,000 | 10 |
| 18 | 1¼ | Crane Chain....... ........... | 338.5 | 15.00 | 50,000 | 82,000 | 10 |
| 19 | 1½ | Crane Chain. . . ........... | 416.6 | 21.00 | 70,000 | 116,000 | 10 |

P. R. R.

**159. Specification for the Material and Workmanship of a Steel Stand-Pipe.** The following specification for the material and workmanship suitable for a steel water tower or stand-pipe have been prepared by Mr. Wm. D. Pence, after a very long and careful investigation of the numerous failures which have occurred in such structures and also of the mate-

rials and workmanship suitable and necessary for this kind of work. The specification includes a phosphorus limit of 0.06 of one per cent., which is the same as that specified in article 156. There is no question but that a limit of from 0.06 to 0.08 of one per cent. is necessary in order to exclude high phosphorus steels which are of necessity brittle. The author heartily commends these specifications, not only for the purpose named, but for all similar kinds of work.

*Material.*—The metal composing the stand-pipe shall be soft, open-hearth steel, containing not more than 0.06 per cent. phosphorus, and having an ultimate tensile strength of not less than 54,000 nor more than 62,000 pounds per square inch, an elastic limit not less than one-half the ultimate strength, an elongation of not less than 26 per cent. in eight inches and a reduction of area of not less than 50 per cent. at fracture, which shall be silky in character. Before or after being heated to a cherry red and quenched in water at 80 deg. F., the steel shall admit of bending while cold, flat upon itself, without sign of fracture on the outside of the bent portion.

*Test Pieces.*—All test samples shall be cut from finished material. Tensile test pieces to be at least 16 inches long, and to have for a length of 8 inches a uniform planed-edged sectional area of at least ½ square inch, the width in no case to be less than the thickness of the piece. Bending test pieces to be 12 inches long, and to have a width of not less than four times the thickness, with edges filed smooth.

*Number of Tests.*—For the purpose of identification the number of the melt or heat of steel shall be stamped on each plate produced therefrom. At least one full series of tests, both chemical and physical, as above specified, shall be made of each melt, and such additional tests may be made as, in the judgment of the inspector, seem essential for corroborative purposes under varying conditions or methods of treatment of the metal.

*Finish of Material.*—All plates must be free from laminations and surface defects, and shall be rolled truly to the specified thicknesses.

*Facilities for Testing.*—Complete facilities for the tests and inspections shall be provided by the contractor, as required.

*Inspector.*—Material will be inspected at the mill by (name of a trustworthy testing concern equipped to make both chemical and physical tests) or such other party as may be approved by the engineer.

*Additional Test Pieces.*—If required by the engineer, the contractor will provide four certified samples of each thickness of plate used in the work, these samples to be 2 inches wide and 16 inches long.

*Workmanship.*—All workmanship must be first-class in every particular.

*Working Steel.*—The plates and angles shall be shaped to the proper curvature by cold rolling. No heating and hammering shall be allowed for straightening or curving, or for other purposes.[1]

*Punching.*—The work shall be carefully and accurately laid out in the shop, and the rivet holes punched with a center punch, sharp and in perfect order, from the surface to be in contact. The diameter of the punch shall not exceed that of the rivet by more than 1-16 inch, and the diameter of the die shall in no case exceed that of the punch by more than 1-16. Rivet holes in plates having a thickness of ¾ inch, and over shall either be drilled or if punched, shall be reamed not less than ⅛ inch larger than the die sides of the holes, and sharp edges shall be trimmed.

*Beveling, etc.*—All calking edges shall be planed to a proper bevel. All parts must be adjusted to a perfect fit, and properly marked before leaving the shop.

*Erection.*—In assembling the work, the rivet holes shall match so that hot rivets may be inserted without the use of a hammer. Drifting is prohibited. Eccentric holes, if any, must be reamed, and if required, larger-sized rivets shall be used in such holes.

*Rivets and Riveting.*—The best grade of soft charcoal iron rivets to be had in the market shall be used. Sufficient stock must be provided in the rivets to completely fill the holes and make a full head. The rivets shall be driven at such a heat as will admit of their being finished in good form with a button set before the rivet has cooled to a critical point. As often as may be deemed advisable for the purpose of testing the work, rivets shall be cut out at the direction of the inspector. The quality of the rivet metal and of the workmanship shall be such that the fracture of the rivet so removed at random shall show a good, tough, fibrous structure without any crystalline appearance, and there shall be no evidence of brittleness. Loose rivets must be promptly replaced, no rivet calking being permitted.

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[1] If lap riveting is used, omit the expression "or for other purposes," and insert the following sentence: "No scarfing shall be done at a temperature below that of ignition of a hard-wood hammer handle, and no work shall be done upon the steel between such temperature and that of boiling water."

*Calking.*—All seams must be calked thoroughly tight with a round-nosed calking tool by workmen of acceptable skill. Great care must be taken not to injure the under plate.

*Rejections.*—Defective material and workmanship may be rejected at any stage of the work, and must be properly replaced by the contractor as directed.

*Final Tests.*—After completion the work shall be tested by filling the stand-pipe with water, and the leaks, if any, shall be promptly and thoroughly calked. The stand-pipe must be water-tight before acceptance.

*Superintendence.*—All inspections shall be made under the direction of the engineer who shall have general supervision of the work. W. D. P.

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## MISCELLANEOUS SPECIFICATIONS.

**160. Specifications for Pile and Trestle Bridging.** The following specifications for pile foundations and timber trestles are those used by the Union Pacific Railway Co. These specifications may, however, serve as a standard for all kinds of pile foundations, and for the selection of large timbers for engineering structures. The formula for obtaining the safe bearing resistance of pile foundations is that generally known as the "Engineering News formula:"

All piles to be made from straight, sound, live timber, free from cracks, shakes and rotten knots, cut from the following kinds of timber: White oak, burr oak, red or yellow Oregon fir. They must be so straight that a straight line taken in any direction from the center of each end of the pile, and run the length of it, shall show that the pile is at no point over one-eighth of its diameter at such point out of a straight line. They must show an even, gradual taper from end to end. Ends must be cut square, all bark taken off, branches and knots trimmed off smooth, finishing the pile in a workmanlike manner. They must not be less than fourteen (14) inches in diameter at the narrowest point of measurement of butt or large end, nor less than ten (10) inches in diameter at narrowest point of measurement of point or small end, and at no part more than seventeen (17) inches in diameter.

All piles must be properly sharpened before driving. They

must be driven until they will carry a safe working load of —— pounds, computed by the following formula:

$$L = \frac{2\,wh}{s+1}$$

In which L=Safe load in pounds.
w=Weight of hammer in pounds.
h=Fall of hammer in feet.
s=Last penetration in inches.

They will be estimated and paid for by the lineal foot. 1. As delivered at the site of the structure, according to bills furnished by the engineer. 2. For driving, straightening and cutting off ready for the caps, and only the length actually left standing in the structure to be paid for.

All timbers must be of the exact dimensions given and figured on the plans, to be cut from sound, live timber, free from loose or rotten knots, worm holes, wind shakes or splits; reasonably well seasoned, straight grained, square edged, and free from any and every defect calculated to impair its strength and durability. It will be estimated and paid for in the work by the thousand feet, board measure. The following kinds of timber will be accepted:

All bridge ties will be white or burr oak, Oregon red or yellow fir, tamarack or yellow pine.

All track stringers and guard timbers will be Oregon fir or yellow pine, of the long leaved, southern hard pine variety.

All posts, caps, sills, bracing and end plank will be white or burr oak, red or yellow Oregon fir, white or yellow pine or tamarack.

All wrought iron must be of the best quality of refined iron, tough, ductile and capable of standing a tensile strain of fifty thousand (50,000) pounds per square inch of sectional area. The manufacture of the bolts must be perfect in every respect, and have nuts and screws of the United States standard dimensions, length of thread to be not less than three inches.

All washers and spacing blocks, etc., must be well manufactured of good gray iron and to the exact dimensions shown on the drawing. The cost of placing all bolts, spikes and washers in the structure will be included in the price paid for framing and erecting the timber.

All bridge ties will be furnished and placed in the bridges by the contractor.

The surface of the ties must be brought to a true plane under the rail, so that the rail will get a full bearing on every tie.

All of the track stringers shall be brought to a true plane, so that ties will get an even bearing on all the stringers.

Where any timber or pile trestle bridge is built on a curve, the blocking for elevating the outer rail, or other means for elevating it, will be as per drawings for the same, a copy of which will be furnished from the office of the chief engineer.

The culverts will be put in place and finished ahead of the grading, so that it will not interfere with or detain the grading, in any way.

Bridging shall begin when directed by the engineer, and progress at a rate sufficiently rapid to keep out of the way of the tracklayers.

When directed by the engineer drain pipes will be used instead of culverts; they will be of cast iron or vitrified terra cotta; this will be carefully bedded and jointed and of such size as may be directed by the engineer.

All framing shall be accurately fitted; no blocking or shimming will be allowed in making joints; the holes for the bolts shall be bored with an auger of the exact size of the bolts. The nuts on all bolts shall be screwed so the washers shall pinch hard upon the wood and bring all the parts of the structure close together.

On completion pick up and remove all rubbish from the premises.

All material will be inspected on the above specifications, at points of shipment or destination as agreed, and the owners required to remove all rejected material from the company's premises within thirty (30) days from the date of notice to do so. The company after that time will not be responsible for the return or safe keeping of the same.

When from any cause bridge materials are unloaded from cars at material yards or end of track, it shall be reloaded by the contractor at his own expense. U. P. R'y.

**161. Specifications for the Steam Plant of a Small Electric Light Station.** The following specification for the steam plant of a small electric light station includes specifications for the engine and its attachments, feed water heater, boiler feed-pumps, boilers, furnace, stack and pipe connections. While not especially elaborate, they have been prepared by a mechanical engineer of large experience in this field of practice. They are given here, however, not for the purpose of being copied, but simply as an illustration of such a specification. The reader will note that three kinds of engines have been provided for, and that large liberty is retained by the engineer in the selection of the engine from those submitted for competition in the

bids. A particular feed water heater was here specified, because it was thought to be best suited for the kind of water which was to be used, the advantage of this heater being that it largely removes the scale from hard water before it enters the boiler:

ENGINE.

*Type.*—There will be one engine, of the high speed automatic pattern; cylinders 10½ inches or 11 inches diameter; capable of operating continuously at 600 feet piston speed per minute, without undue heating.

*Regulation.*—The automatic governor must permit a cut-off as late as ½; and must be so adjusted, that the difference in speed, when running with 100 pounds initial pressure and no load, as compared with 75 pounds initial pressure and cut-off ½, shall not exceed a guaranteed amount to be stated by bidder; with a correspondingly less variation inside of the limits named. The regulator must be so constructed as to permit this guaranteed regulation to be easily maintained, without racing.

*Fixtures and Fittings.*—Standard cast iron sub-base, and two heavy driving pulleys, of such diameter and face as may be required to suit dynamo pulleys; a full set of foundation bolts, nuts and plates; template for foundation; throttle and drain valves; cylinder lubricators, automatic oil cups, wrenches, indicator motion, etc.; and two one-inch relief valves set at 110 pounds pressure.

*Dimensions.*—State diameter and material of shaft and crank pin, and submit drawing or blue print indicating clearly size of cylinders, speed, diameter of pipe openings, space occupied and dimensions of foundations.

*Corliss Engine.*—Bids will also be considered under the same conditions on a Corliss engine; 11 inches diameter of cylinder, shaft 6 inches; flywheel and frame extra heavy; speed 100. Regulation to be guaranteed.

*Direct Connected Engines.*—This type will also be considered, together with suitable dynamo. High speed. Vertical or horizontal. Compound or single expansion. Full details must accompany proposals.

*Belting.*—Double thickness, even and pliable, equivalent in strength and adhesiveness to the Shultz leather belting. Of selected stock, stretched twice before being made into belts. No shoulders or flank leather to be used. Its tensile strength must not be less than 3,200 pounds per square inch of section, and

must not be worked beyond 65 pounds per inch of width. The belt will be thoroughly stretched again after making, and before shipment.

### FEED WATER HEATER.

One No. 5 Hoppes exhaust steam feed water heater and purifier capable of heating 3,000 pounds of water per hour to the highest point attainable, without back pressure on the engine. To have steel shell, oil extractor and trap; crane for removing head; automatic water regulator and openings for water and steam as required.

### BOILER FEED PUMPS.

One Worthington duplex pump, 5¼x3½x5, water ends to have packed pistons. Piston rods, water cylinder linings and water pistons to be of gun metal. Valves suitable for hot water; complete with a full set of oil cups and wrenches.

### BOILERS.

To be two in number as follows:

*Dimensions.*—Fifty-four inches diameter, eighteen feet long; thickness of shells, five sixteenths; heads, seven sixteenths, to have half smoke-box extension, bolted on, sixteen inches in length.

*Material.*—Park Bros.' Open Hearth Homogeneous flange steel of 60,000 pounds tensile strength. All plates to be stamped with name of maker, quality and tensile strength.

*Construction.*—The heads are to be machine flanged, to have an easy radius; and amply braced, with braces of best refined iron, uniformly distributed, so that each brace will carry its full share of strain. Before beginning construction a plan of the bracing proposed must be submitted to the engineer for approval.

*Tubes.*—Thirty-eight—4 inches in diameter, 18 feet long, of lap welded, charcoal iron; carefully and properly expanded and beaded over.

*Dome.*—Thirty inches diameter, thirty inches high. To be of same material as shell; well braced and double riveted.

*Seams.*—There will be one longitudinal, double riveted seam, in each sheet, well removed from the fire. Other riveting single. The make, size and spacing of rivets shall be in accordance with the best modern engineering practice.

*Supports.*—There will be two extra heavy cast iron lugs for each side; each 4½ feet from end of the boiler. The forward lugs to rest directly on cast iron plates 12 inches square, sup-

ported by the masonry. The rear lugs will rest upon 9 one-inch rollers, which in turn will rest upon 12x12 plates.

*Stack.*—Of sheet steel, No. 12 gauge in thickness, diameter 32 inches, height 50 feet. Lower end Y shaped to fit stack plates. Furnish sufficient ⅜ inch galvanized iron guy wire to make two complete sets of guys. Support stack underneath Y to brick work or floor.

*Fittings.*—One 5-inch chime whistle; one soot sucker, complete, with hose and handle; one flue scraper; one steel barrow; complete set of firing tools, consisting of shovel hoe, slice-bar and poker; 2 eight-inch steam gauges; 2 one and one-quarter inch combination water columns, with gauge cocks, and water glasses; two 4-inch safety valves, with levers marked to 150 pounds pressure; 2-inch check, stop and blow-off valves.

*Castings.*—Two square top, full flush fronts of approved ornamental design, with tight fitting doors, and anchor rods extending the entire length of brick work; six 9-foot binding bars with cross and anchor rods; soot door and frame; stack plate and damper. Cast iron skeleton frames suitable for standard sizes of fire brick, to be used in place of back plates. Rocking grates will be furnished and erected by the city.

*Openings.*—The man hole in front head under tubes, and one in shell back of dome, both properly reinforced, and provided with heads, arches and bolts complete; two 1¼ inch openings for water column; one 2-inch for feed and blow off pipe; one 4-inch main steam outlet, and one 4-inch for safety valve; all to be properly reinforced and located as directed by the engineer.

*Inspection and Insurance.*—Before shipment the boilers will be tested and made tight under a water pressure of 150 pounds. Certificate of inspection and insurance policy in the Hartford Steam Boiler Inspection and Insurance Company, for the sum of $500, for one year must be furnished, for each boiler.

## FOUNDATIONS AND BRICK WORK.

(See Drawing.)

The dimensions of foundations for engine, boilers, heaters, pumps and brick work for furnaces, will be clearly shown in drawings, which must be accurately followed.

*Foundations.*—All are to be of concrete composed of one part best domestic cement, three parts of clean, sharp sand, and five parts clean, broken stone of sizes that will pass through a 2½ inch ring; all to be thoroughly mixed, laid quickly, and rammed down solid.

*Excavations.*—As per drawing. Remove promptly all earth and other debris. Bottom to be level, and rammed if necessary.

*Iron Work.*—All bolts and plates for engines and dynamos must be put thoroughly and permanently into position by the contractor. Outside of each bolt place a piece of 2-inch iron pipe, so as to permit some adjustment of the bolts.

*Cap Stones.*—Foundations for heater, and boiler feed pumps will project somewhat above floor line. Each of these will be surmounted by a neatly cut cap stone, 8 inches thick and of proper dimensions.

*Boiler Furnaces.*—To be of well burned red brick, thoroughly wetted before laying; all joints flushed solid; all courses level and straight. Every sixth course both inside and outside to be a header. Brick to be laid in mortar composed of one part lime to five parts of sharp sand. Build into side and rear walls a 1-inch air space, which shall be air tight; except immediately under the supporting lugs of boilers, where the walls shall be carried up solid.

*Fire Brick Lining.*—The entire inside of the furnace where exposed to flame, will be lined with A No. 1 hard burned fire brick, laid in dry milled fire clay, with very thin joints, flushed full; headers every sixth course. Use the following special fire brick "Angle B," to form the top and front corner of same, use the "4½ to give the batter on front of bridge wall: at top and bottom, Jamb," also for the inner corners of cleaning out doors openings. Front of bridge all headers.

*Closing In Tile.*—For the sides of furnace, use fire brick tile 6x12x2¼; and for the rear above tubes lay ordinary fire brick special skeleton arch frame.

*Iron Work.*—Place in position all cleaning out doors, cast iron plates and anchor rods.

PIPE CONNECTIONS.

To be as per drawing, which will be furnished.

*Steam.*—Four inches from boiler to 6-inch header leading to engine room, where it will reduce to size required by engine, thence to engine proper size, through a Hine separator suitably drained. Leave Tee having plugged outlets for additional engine and water works pump.

*Exhaust.*—Four inches from engine to main line; thence 6 inches through heater to 5 feet above roof. Leave plugged inlet Tee for additional engine and pump.

*Drains.*—Both the steam and exhaust pipes are to have suitable drains of ample size wherever there is any possibility of water accumulating. Run these drains outside of building.

*Small Piping.*—Feed, blow-off and steam and exhaust pipes for boiler feed pumps to be as per details shown in drawing.

*Fittings.*—Of the best construction, with threads true and clean. Use in all cases what is known as "water" or "sweep" ells and fittings, having extra long radii for curves.

*Valves.*—Of the Jenkin Brothers, or asbestos disk pattern. Use gate and angle valves in preference to globe. When globe valves are used they must be so placed as not to form water pockets.

*Supports.*—All pipe work to be well supported in such a way as to bring no unusual strain on the pipe or fittings; either from their weight, or from expansion or contraction.

*Covering.*—All live steam pipes, domes and top of boilers to be covered with a high grade non-conducting material, such as magnesia sectional pipe covering.

*In General.*—The arrangement of the pipe work must be such as to provide for all differential strains arising from expansion and contraction. The work to be of the best and most thorough possible. The steam pipe will be tested to 150 pounds.

W. H. B.

**162. Specifications for Leather Driving Belts.** The following specifications for large leather belts were prepared for the large water power electric plant at Austin, Texas, in 1894. It is thought they conform to the latest and best practice in the manufacture of leather belting:

There are to be six main driving belts and seven belts to drive dynamos, of dimensions as hereinafter scheduled.

These belts are to be of leather made from the best selected, large steer hides, of pure oak-bark tannage. The cuts are to be taken from the centre solid portions of the hides, and are not to include shoulders, flank or soft parts of the hides. Each piece is to be of fine, close fibres and all pieces are to be scarfed to a uniform thickness. No piece taken from one hide is to exceed a net length of fifty inches.

The individual pieces of the leather are to be thoroughly stretched after currying and again machine tested and the utmost stretch, within elastic limits, given to the belts when they have been made up complete.

The transverse lap joints are not to exceed four inches in longitudinal length, are to be scarfed in the best manner, thoroughly cemented and are to be made fast and durable without the use of pegs or rivets. All belt edges are to be properly rounded.

All belts are to be thoroughly water-proofed.

The complete belts are to be soft, pliable and finished with smooth polished surfaces.

The belts of thirty-eight inch width are to be of double thickness. The outer face pieces are each to be in a single width, with centre conforming to the back-bone centre of the hide. The inner, or running face pieces of the thirty-eight inch belts are to be nineteen inches in net width and to have one and one-half inch scarfed and lapped longitudinal joints. One edge of each half-width will be cut along the back-bone centre of the hide and in the makeup of the belt, these inside half widths are to be placed with the back-bone edges at the outer edges of the belt. These seam sides of the thirty-eight inch belts are to be run next the pulleys.

All the remaining belts are to be of double thickness in single width pieces, with centres of each piece conforming to the back-bone centres of the hide. The belts are to be finished with uniform thicknesses respectively not less than as follows for each stated width:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 38 | inches | width | of not | less than | $\frac{28}{64}$ | inches | thickness. |
| 25 | " | " | " | " | $\frac{24}{64}$ | " | " |
| 24 | " | " | " | " | $\frac{26}{64}$ | " | " |
| 14 | " | " | " | " | $\frac{24}{64}$ | " | " |
| 13 | " | " | " | " | $\frac{24}{64}$ | " | " |
| 11 | " | " | " | " | $\frac{22}{64}$ | " | " |

The speeds of the belts will be at rates of about 5,000 lineal feet per minute.

All these belts are to be transported to the power house now being constructed by the board of public works of Austin, Texas, in Austin, and are to be placed upon the pulleys in the power house and spliced and cemented in place.

The hides and manufacture, finish and fitting of the belts are to be first-class in every respect and the belts are to be guaranteed to run smoothly and straight upon the pulleys and to work successfully for the space of one year from the time of the starting up of the power house for regular work.

If any defect tending to impair the usefulness or life of any belt supplied under this specification, shall develop within one

year that belt shall at once be made good by the manufacturer or replaced by a belt conforming with this specification.

Proposals for these belts, as fitted in place ready for the starting of the machines, are to be delivered to the Hon. John McDonald, mayor and president of the board of public works, Austin, Texas, on or before the 8th day of December, 1894, and all belts are to be delivered and fitted in place ready for use within six weeks of the date of the order for their manufacture and delivery.

The board of public works reserves the right to reject any and all proposals as may be for the best interest of the city of Austin.

Blue-prints showing relative positions of the pulleys and inclinations of the belts are submitted herewith.

SCHEDULE OF BELTS.

| | | Width of Belt | Thickness in 64ths of an inch | Diameter of Driving Pulley. | Diameter of Driven Pulley. | Distance between Centres of Shafts | Total Net Length Belt in Place |
|---|---|---|---|---|---|---|---|
| | H P | In | 64ths | In | In | Feet. | Feet. |
| Main Driving Belt | 520 | 38 | 28 | 54 | 54 | 43 108 | 100 383 |
| " " " | 520 | 38 | 28 | 54 | 54 | 42 763 | 99 663 |
| " " " | 201 | 25 | 24 | 54 | 26 | 44 970 | 100 412 |
| " " " | 201 | 25 | 24 | 54 | 26 | 48.075 | 106 622 |
| " " " | 201 | 25 | 24 | 54 | 26 | 45 379 | 101 280 |
| " " " | 201 | 25 | 24 | 54 | 26 | 48 687 | 107.846 |
| Dynamo Belt | 241 | 24 | 26 | 56 | 32 | 17 851 | 47 352 |
| " " | 184 | 14 | 24 | 50 | 28 | 18 625 | 47.222 |
| " " | 134 | 14 | 24 | 50 | 26 5 | 17 688 | 45 348 |
| " " | 100 | 13 | 24 | 55 | 18 | 15 293 | 39 708 |
| " " | 100 | 13 | 24 | 55 | 18 | 15 293 | 30 708 |
| " " | 80 | 11 | 21 | 46 | 18 | 15.211 | 38.800 |
| " " | 80 | 11 | 22 | 46 | 18 | 19 912 | 48 102 |

J. T. F.

**163. Specifications for Pumps to be Operated by Water Power.** The following specification was prepared for the city of Austin, Texas, in 1892, for the construction of two pumps for a city water supply to be driven by water power machinery:

PUMPS.—There are to be two pairs of horizontal, double-acting, plunger pumps, having two pump cylinders to each pair. Each pair of pumps is to have capacity to deliver four million gallons of water per 24 hours.

The dimensions of plunger will be approximately as follows: 1½ foot diameter, 2¾ foot stroke, with 25 revolutions per minute; the plunger speed not to exceed a mean rate of 137½ feet per minute when pumping water at the rate of four million gallons per twenty-four hours.

These pumps are to be adapted for pumping to a reservoir and also for pumping directly into the city distribution pipes with direct pressure, the pump house being located between the reservoir and the city. The static head of the reservoir is 245 feet and the dynamic head approximately 265 feet and the force main to the reservoir is 7,600 feet in length, of 24 inch pipe.

These pumps are to receive motion from vertical turbine shafts having beveled gears which drive a jack shaft. On the jack shaft is to be a spur pinion, which will drive a spur mortise gear on the main pump shaft. On each end of the main shafts are to be balanced crank disks, which will drive the pumps.

The receiving and delivery chambers are to be ample in dimensions, and are to have nests of valves of the best bronze composition of approximately 3 inches diameter, and sufficient in number so that the valves shall not lift more than ⅜ inches each when the rate of delivery of the pumps is at four million gallons per day. The pump chambers will be well provided with hand-holes that will give easy access to each of the valves.

The water supply for each pair of pumps is to be taken from a 30-inch branch in the horizontal penstock in the basement beneath the pump room floor. The necessary admission and discharge pipes, of ample size and easy curves, and a tall air vessel for each pair of pumps are to be provided. The force mains will be connected with the force mains leading to the reservoir, on the outside of the pump house wall, and not exceeding 10 feet distance from the face of the wall.

The pump cylinders will be connected with the main and jack shaft pillow blocks by continuous, heavy cast-iron girders, adapted to carry the bearings and the strains of the connecting rods without tremble or elasticity.

The main and jack shafts are to be of the best wrought iron forging turned to the diameters indicated upon the drawings, and bossed up to receive the gears. The large gears, of both the spur and bevel pairs, will be mortise gears with their mortises planed, and having thoroughly seasoned, machine cut, smooth maple cogs, fitted and keyed in the most rigid manner. The cogs are to be thoroughly boiled in oil.

Each spur pinion is to be machine moulded, with teeth planed on both sides to match and run with mortise gears. Both gears and pinions are to be bored to fit their respective shafts and to be keyed in place. The pinions are to be feather keyed on the

nicked with a chisel or grooved on a machine, transversely about a sixteenth of an inch (1/16") deep in three places about two inches (2") apart. The first groove should be made on one side, two inches (2") from the square end of the specimen; the second, two inches (2") from it on the opposite side; and the third, two inches (2") from the last and on the opposite side from it. The test specimen is then put in a vise, with the first groove about a quarter of an inch (1/4") above the jaws, care being taken to hold it firmly. The projecting end of the test specimen is then broken off by means of a hammer, a number of light blows being used, and the bending being away from the groove. The specimen is broken at the other two grooves in the same way. The object of this treatment is to open and render visible to the eye any seams due to failure to weld up, or to foreign interposed matter, or cavities due to gas-bubbles in the ingot. After rupture one side of each fracture is examined, a pocket lens being used if necessary, and the length of the seams and cavities is determined.

13. **Yield-point.**—For the purpose of this specification the yield-point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

14. **Sample for Chemical Analysis.**—In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot. An additional check analysis may be made from a tensile specimen of each melt used on an order other than in locomotive fire-box steel. In the case of locomotive fire-box steel a check analysis may be made from the tensile specimen from each plate as rolled.

### VARIATION IN WEIGHT.

15. The variation in cross-section or weight of more than 2½ per cent from that specified will be of sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(*e*) Plates, 12½ pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than 2½ per cent variation above or 2½ per cent below the theoretical weight. When 100 inches wide and over, 5 per cent above or 5 per cent below or the theoretical weight.

(*f*) Plates under 12½ pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, 2½ per cent above or 2½ per cent below the theoretical weight; 75 inches wide up to 100 inches wide, 5 per cent above or 3 per cent below the theoretical weight. When 100 inches wide and over, 10 per cent above or 3 per cent below the theoretical weight.

* * * * * * * * * * *

(*g*) For all plates ordered to gauge there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

### TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over 1/100 inch less than the ordered gauge

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

*Plates 1/4 inch and over in thickness.*

| Thickness of Plate. Inch. | Width of Plate. Up to 75 inches. Per cent. | 75 to 100 inches. Per cent. | Over 100 inches. Per cent. |
|---|---|---|---|
| 1/4 | 10 | 14 | 18 |
| 5/16 | 8 | 12 | 16 |
| 3/8 | 7 | 10 | 13 |
| 7/16 | 6 | 8 | 10 |
| 1/2 | 5 | 7 | 9 |
| 9/16 | 4½ | 6½ | 8½ |
| 5/8 | 4 | 6 | 8 |
| Over 5/8 | 3½ | 5 | 6½ |

*Plates under 1/4 inch in thickness.*

| Thickness of Plate. Inch. | Width of Plate. Up to 50 inches. Per cent. | 50 inches and above. Per cent. |
|---|---|---|
| 1/8 up to 5/32 | 10 | 15 |
| 5/32 " 3/16 | 8½ | 12½ |
| 3/16 " 1/4 | 7 | 10 |

FINISH.

16. All finished material shall be free from injurious surface defects and laminations, and must have a workmanlike finish.

BRANDING.

17. Every finished piece of steel shall be stamped with the melt number, and each plate, and the coupon or test specimen cut from it, shall be stamped with a separate identifying mark or number. Rivet-steel may be shipped in bundles, securely wired together, with the melt number on a metal tag attached.

INSPECTION.

18. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with the specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

## IV. STEEL RAILS.

PROCESS OF MANUFACTURE.

1. (*a*) Steel may be made by the Bessemer or open-hearth process.

(*b*) The entire process of manufacture and testing shall be in accordance with the best standard current practice, and special care shall be taken to conform to the following instructions.

(*c*) Ingots shall be kept in a vertical position in pit-heating furnaces.

(*d*) No bled ingots shall be used.

(*e*) Sufficient material shall be discarded from the top of the ingots to insure sound rails.

CHEMICAL PROPERTIES.

2. Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

| | 50 to 59 + pounds Per cent. | 60 to 69 + pounds. Per cent. | 70 to 79 + pounds. Per cent. | 80 to 89 + pounds Per cent. | 90 to 100 pounds. Per cent. |
|---|---|---|---|---|---|
| Carbon.................... | 0 35–0 45 | 0.38–0 48 | 0.40–0 50 | 0.43–0.53 | 0.45–0.55 |
| Phosphorus shall not exceed | 0.10 | 0 10 | 0.10 | 0.10 | 0.10 |
| Silicon shall not exceed..... | 0 20 | 0.20 | 0 20 | 0.20 | 0.20 |
| Manganese............... | 0 70–1.00 | 0 70–1 00 | 0.75–1.05 | 0.80–1.10 | 0.80–1.10 |

PHYSICAL PROPERTIES.

3. **Drop Test.** One drop test shall be made on a piece of rail not more than six feet long, selected from every fifth blow of steel. The rail shall be placed head upwards on the supports, and the various sections shall be subjected to the following impact tests:

| Weight of Rail. Pounds per yard. | Height of Drop. Feet. |
|---|---|
| 45 to and including 55 | 15 |
| More than 55 " 65 | 16 |
| " 65 " 75 | 17 |
| " 75 " 85 | 18 |
| " 85 " 100 | 19 |

If any rail break when subjected to the drop test, two additional tests will be made of other rails from the same blow of steel; and if either of these latter tests fail, all the rails of the blow which they represent will be rejected; but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted. If the rails from the tested blow shall be rejected for failure to meet the requirements of the drop test as above specified, two other rails will be subjected to the same tests, one from the blow next preceding, and one from the blow next succeeding the rejected blow. In case the first test taken from the preceding or succeeding blow shall fail, two additional tests shall be taken from the same blow of steel, the acceptance or rejection of which shall also be determined as specified above, and if the rails of the preceding or succeeding blow shall be rejected, similar tests may be taken from the previous or following blows, as the case may be, until the entire group of five blows is tested, if necessary.

The acceptance or rejection of all the rails from any blow will depend upon the result of the tests thereof.

TEST PIECES AND METHODS OF TESTING.

4. **Drop-testing Machine.**—The drop-test machine shall have a tup of two thousand (20000) pounds weight, the striking face of which shall have a radius of not more than five inches (5″), and the test rail shall be placed head upwards on solid supports three feet (3′) apart. The anvil-block shall weigh at least twenty thousand (20,000) pounds, and the supports shall be a part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the tests were made.

5. **Sample for Chemical Analysis.**—The manufacturer shall furnish the inspector, daily, with carbon determinations of each blow, and a complete chemical analysis every twenty-four hours representing the average of the other elements contained in the steel. These analyses shall be made on drillings taken from a small test ingot.

FINISH.

6. **Section.**—Unless otherwise specified, the section of rail shall be the American Standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with paragraph No. 7, relative to specified weight. A variation in height of one sixty-fourth of an inch (1/64″) less and one thirty-second of an inch (1/32″) greater than the specified height will be permitted. A perfect fit of the splice-bars, however, shall be maintained at all times.

7. **Weight.**—The weight of the rails shall be maintained as nearly as possible, after complying with paragraph No. 6, to that specified in contract. A variation of one-half of one per cent (1/2%) for an entire order will be allowed. Rails shall be accepted and paid for according to actual weights.

8. **Length.**—The standard length of rails shall be thirty feet (30′). Ten per cent (10%) of the entire order will be accepted in shorter lengths, varying by even feet down to twenty-four feet (24′). A variation of one-fourth of an inch (1/4″) in length from that specified will be allowed.

9. **Drilling.**—Circular holes for splice-bars shall be drilled in accordance with the specifications of the purchaser. The holes shall accurately conform to the drawing and dimensions furnished in every respect, and must be free from burrs.

10. **Finish.**—Rails shall be straightened while cold, smooth on head, sawed square at ends, and, prior to shipment, shall have the burr occasioned by the saw cutting removed, and the ends made clean. Number 1 rails shall be free from injurious defects and flaws of all kinds.

BRANDING.

11. The name of the maker, the month and the year of manufacture, shall be rolled in raised letters on the side of the web, and the number of the blow shall be stamped on each rail.

INSPECTION.

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is

furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

NO. 2 RAILS.

13. Rails that possess any injurious physical defects, or which for any other cause are not suitable for first-quality, or number 1 rails, shall be considered as number 2 rails, provided, however, that rails which contain any physical defects which seriously impair their strength shall be rejected. The ends of all number 2 rails shall be painted in order to distinguish them.

## V. STEEL SPLICE-BARS.

PROCESS OF MANUFACTURE.

1. Steel for splice-bars may be made by the Bessemer or open-hearth process.

CHEMICAL PROPERTIES.

2. Steel for splice-bars shall conform to the following limits in chemical composition:

| | Per cent. |
|---|---|
| Carbon shall not exceed | 0.15 |
| Phosphorus shall not exceed | 0.10 |
| Manganese | 0.30 to 0.60 |

PHYSICAL PROPERTIES.

3. **Tensile Tests.**—Splice-bar steel shall conform to the following physical qualities:

| | |
|---|---|
| Tensile strength, pounds per square inch | 54,000 to 64,000 |
| Yield-point, pounds per square inch | 32,000 |
| Elongation, per cent, in eight inches shall not be less than | 25 |

4. **Bending Tests.**—(*a*) A test specimen cut from the head of the splice-bar shall bend 180° flat on itself without fracture on the outside of the bent portion.

(*b*) If preferred the bending test may be made on an unpunched splice-bar, which, if necessary, shall be first flattened, and shall then be bent 180° flat on itself without fracture on the outside of the bent portion.

TEST PIECES AND METHODS OF TESTING.

5. **Test Specimen for Tensile Test.**—A test specimen of eight inches (8″) gauged length, cut from the head of the splice-bar, shall be used to determine the physical properties specified in paragraph No. 3.

6. **Number of Tensile Tests.**—One tensile-test specimen shall be taken from the rolled splice-bars of each blow or melt, but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

7. **Test Specimen for Bending.**—One test specimen cut from the head of the splice-bar shall be taken from a rolled bar of each blow or melt, or if preferred the bending test may be made on an unpunched splice-bar, which, if necessary, shall be flattened before testing. The bending test may be made by pressure or by blows.

8. **Yield-point.**—For the purposes of this specification, the yield-point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

9. **Sample for Chemical Analysis.**—In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot.

FINISH.

10. All splice-bars shall be smoothly rolled and true to templet. The bars shall be sheared accurately to length and free from fins and cracks, and shall perfectly fit the rails for which they are intended. The punching and notching shall

accurately conform in every respect to the drawing and dimensions furnished. A variation in weight of more than 2½ per cent from that specified will be sufficient cause for rejection.

BRANDING.

11. The name of the maker and the year of manufacture shall be rolled in raised letters on the side of the splice-bar.

INSPECTION.

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer, to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

## VI. STEEL AXLES.

PROCESS OF MANUFACTURE.

1. Steel for axles shall be made by the open-hearth process.

CHEMICAL PROPERTIES.

2. There will be three classes of steel axles which shall conform to the following limits in chemical composition:

| | Car, engine-truck, and tender-truck axles. Per cent. | Driving-wheel axles (Carbon steel.) Per cent. | Driving-wheel axles. (Nickel steel.) Per cent. |
|---|---|---|---|
| Phosphorus shall not exceed........ | 0.66 | 0.06 | 0.04 |
| Sulphur " " " ........ | 0.06 | 0.06 | 0.04 |
| Nickel " " " ........ | .... | .... | 3.75 |

PHYSICAL PROPERTIES.

3. **Tensile Tests.**—For car, engine-truck, and tender-truck axles no tensile test shall be required.

4. The minimum physical qualities required in the two classes of driving-wheel axles shall be as follows:

| | Driving wheel axles. (Carbon Steel) | Driving-wheel axles. (Nickel Steel.) |
|---|---|---|
| Tensile strength, pounds per square inch........ | 80,000 | 80,000 |
| Yield-point, pounds per square inch ............ | 40,000 | 50,000 |
| Elongation, per cent, in two inches.............. | 18 | 25 |
| Contraction of area, per cent.................... | ...... | 45 |

5. **Drop Tests.**—One axle selected from each melt, when tested by the drop test described in paragraph No. 9, shall stand the number of blows at the height specified in the following table without rupture and without exceeding, as the result of the first blow, the deflection given. Any melt failing to meet these requirements will be rejected:

| Diameter of axle at centre, Inches. | Number of blows. | Height of drop. Feet. | Deflection. Inches. |
|---|---|---|---|
| 4¼ | 5 | 24 | 8¼ |
| 4⅜ | 5 | 26 | 8½ |
| 4 7/16 | 5 | 28½ | 8¼ |
| 4⅝ | 5 | 31 | 8 |
| 4¾ | 5 | 34 | 8 |
| 5⅜ | 5 | 43 | 7 |
| 5⅞ | 7 | 48 | 5½ |

6. Carbon-steel and nickel-steel driving-wheel axles shall not be subject to the above drop test.

TEST PIECES AND METHODS OF TESTING.

7. **Test Specimen for Tensile Test.**—The standard turned test specimen, one-half inch (1/2″) diameter and two inches (2″) gauged length, shall be used to deter-

BRANDING.

10. **Tires shall be stamped with the maker's brand and number in such a manner that each individual tire may be identified.**

INSPECTION.

11. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment.

## VIII. STEEL FORGINGS.

PHYSICAL PROPERTIES.

1. **Tensile Tests.**—The minimum physical qualities required of the different-sized forgings of each class shall be as follows.

| Tensile Strength. | Yield-point. | Elongation in 2". | Contraction of Area. | |
|---|---|---|---|---|
| Pounds per Square Inch. | | Per Cent. | | |
| | | | | SOFT STEEL OR LOW CARBON STEEL. |
| 58,000 | 29,000 | 28 | 35 | For solid or hollow forgings, no diameter or thickness of section to exceed 10". |
| | | | | CARBON STEEL NOT ANNEALED. |
| 75,000 | 37,500 | 18 | 30 | For solid or hollow forgings, no diameter or thickness of section to exceed 10". |
| | | | | CARBON STEEL ANNEALED. |
| | Elastic Limit. | | | |
| 80,000 | 40,000 | 22 | 35 | For solid or hollow forgings, no diameter or thickness of section to exceed 10". |
| 75,000 | 37,500 | 23 | 35 | For solid forgings, no diameter to exceed 20" or thickness of section 15". |
| 70,000 | 35,000 | 24 | 30 | For solid forgings, over 20" diameter. |
| | | | | CARBON STEEL, OIL TEMPERED. |
| 90,000 | 55,000 | 20 | 45 | For solid or hollow forgings, no diameter or thickness of section to exceed 3". |
| | | | | CARBON STEEL, OIL TEMPERED. |
| 85,000 | 50,000 | 22 | 45 | For solid forgings of rectangular sections not exceeding 6" in thickness or hollow forgings, the walls of which do not exceed 6" in thickness. |
| 80,000 | 45,000 | 23 | 40 | For solid forgings of rectangular sections not exceeding 10" in thickness or hollow forgings, the walls of which do not exceed 10" in thickness. |
| | | | | NICKEL STEEL ANNEALED. |
| 80,000 | 50,000 | 25 | 45 | For solid or hollow forgings, no diameter or thickness of section to exceed 10". |
| 80,000 | 45,000 | 25 | 45 | For solid forgings, no diameter to exceed 20" or thickness of section 15". |
| 80,000 | 45,000 | 24 | 40 | For solid forgings, over 20" diameter. |
| | | | | NICKEL STEEL, OIL TEMPERED. |
| 95,000 | 65,000 | 21 | 50 | For solid or hollow forgings, no diameter or thickness of section to exceed 3". |
| 90,000 | 60,000 | 22 | 50 | For solid forgings of rectangular sections not exceeding 6" in thickness or hollow forgings, the walls of which do not exceed 6" in thickness. |
| 85,000 | 55,000 | 24 | 45 | For solid forgings of rectangular sections not exceeding 10" in thickness or hollow forgings, the walls of which do not exceed 10" in thickness. |

BRANDING.

13. Each axle shall be legibly stamped with the melt number and initials of the maker at the places marked on the print or indicated by the inspector.

INSPECTION.

14. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment.

## VII. STEEL TIRES.

PROCESS OF MANUFACTURE.

1. Steel for tires may be made by either the open-hearth or the crucible process.

CHEMICAL PROPERTIES.

2. There will be three classes of steel tires which shall conform to the following limits in chemical composition:

| | Passenger Engines. Per Cent. | Freight Engine and Car Wheels. Per Cent. | Switching Engines. Per Cent. |
|---|---|---|---|
| Manganese shall not exceed.... | 0.80 | 0 80 | 0.80 |
| Silicon shall not be less than... | 0.20 | 0 20 | 0 20 |
| Phosphorus shall not exceed.... | 0 05 | 0.05 | 0.05 |
| Sulphur shall not exceed....... | 0 05 | 0.05 | 0 05 |

PHYSICAL PROPERTIES.

3. **Tensile Tests.**—The minimum physical qualities required in each of the three classes of steel tires shall be as follows:

| | Passenger Engines | Freight Engine and Car Wheels. | Switching Engines. |
|---|---|---|---|
| Tensile strength, pounds per square inch.......... | 190,000 | 110,000 | 120,000 |
| Elongation, per cent in two inches....... ....... | 12 | 10 | 8 |

4. **Drop Tests.**—In the event of the contract calling for a drop test, a test tire from each melt will be furnished at the purchaser's expense, provided it meets the requirements. This test tire shall stand the drop test described in paragraph No. 7, without breaking or cracking, and shall show a minimum deflection equal to $D^2 + (40T^2 + 2D)$, the letter $D$ being internal diameter and the letter $T$ thickness of tire at centre of tread.

TEST PIECES AND METHODS ON TESTING.

5. **Test Specimen for Tensile Tests.**—The standard turned test specimen, one-half inch (1/2″) diameter and two inches (2″) gauged length, shall be used to determine the physical properties specified in paragraph No 3. It is shown in Fig. 639.

6. **Location of Tensile Specimens.**—When the drop specimen is specified, this test specimen shall be cut cold from the tested tire at the point least affected by the drop test. If the diameter of the tire is such that the whole circumference of the tire is seriously affected by the drop test, or if no drop test is required, the test specimen shall be forged from a test ingot cast when pouring the melt, the test ingot receiving, as nearly as possible, the same proportion of reduction as the ingots from which the tires are made.

7. **Drop Test Described.**—The test tire shall be placed vertically under the drop, in a running position, on a solid foundation of at least ten tons in weight and subjected to successive blows from a tup weighing 2240 pounds, falling from increasing heights until the required deflection is obtained.

8. **Sample for Chemical Analysis.**—Turnings from the tensile specimen, or drillings from the small test ingot, or turnings from the tire, if preferred by the inspector, shall be used to determine whether the melt is within the limits of chemical composition specified in paragraph No. 2.

FINISH.

9. All tires shall be free from cracks, flaws, or other injurious imperfections, and shall conform to dimensions shown on drawings furnished by the purchaser.

mine the physical properties specified in paragraph No. 4. It is shown in the following sketch :

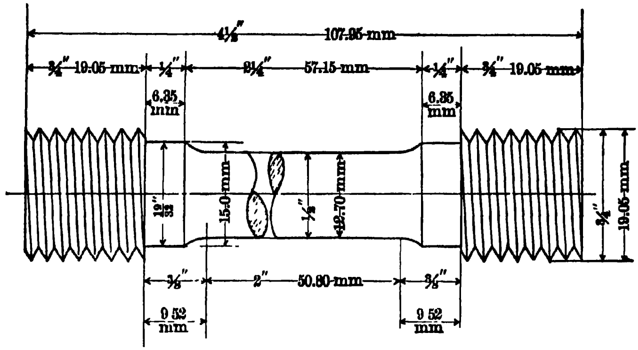


FIG. 639.—SHORT FORM OF STANDARD TENSION-TEST SPECIMEN.

8. **Number and Location of Tensile Specimens.**—For driving axles one longitudinal test specimen shall be cut from one axle of each melt. The centre of this test specimen shall be half-way between the centre and outside of the axle.

9. **Drop Test Described.**—The points of supports on which the axle rests during tests must be three feet apart from centre to centre; the tup must weigh 1640 pounds; the anvil, which is supported on the springs, must weigh 17,500 pounds; it must be free to move in a vertical direction; the springs upon which it rests must be twelve in number, of the kind described on drawing, and the radius of supports and of the striking face on the tup in the direction of the axis of the axle must be five inches (5″). When an axle is tested it must be so placed in the machine that the tup will strike it midway between the ends, and it must be turned over after the first and third blows, and, when required, after the fifth blow. To measure the deflection after the first blow, prepare a straight-edge as long as the axle, by reinforcing it on one side, equally at each end, so that when it is laid on the axle the reinforced parts will rest on the collars or ends of the axle, and the balance of the straight-edge not touch the axle at any place. Next, place the axle in position for test, lay the straight-edge on it, and measure the distance from the straight-edge to the axle, at the middle point of the latter. Then, after the first blow, place the straight-edge on the now bent axle in the same manner as before, and measure the distance from it to that side of the axle next to the straight-edge, at the point farthest away from the latter. The difference between the two measurements is the deflection. The report of the drop test shall state the atmospheric temperature at the time the tests were made.

10. **Yield-point.**—The yield-point specified in paragraph No. 4 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine.

11. **Sample for Chemical Analysis.**—Turnings from the tensile-test specimen of driving axles, or drillings taken midway between the centre and outside of car, engine, and tender-truck axles, or drillings from the same test ingot if preferred by the inspector, shall be used to determine whether the melt is within the limits of chemical composition specified in paragraph No. 2.

FINISH.

12. Axles shall conform in sizes, shapes, and limiting weights to the requirements given on the order or print sent with it. They shall be made and finished in a workmanlike manner, and shall be free from all injurious cracks, seams, or flaws. In centring, sixty- (60-) degree centres must be used, with clearance given at the point to avoid dulling the shop-lathe centres.

PROCESS OF MANUFACTURE.

2. Steel for forgings may be made by the open-hearth, crucible, or Bessemer process.

CHEMICAL PROPERTIES.

3. There will be four classes of steel forgings, which shall conform to the following limits in chemical composition:

| | Forgings of Soft or Low Carbon Steel. Per Cent. | Forgings of Carbon Steel Not Annealed Per Cent. | Forgings of Carbon Steel, Oil-tempered or Annealed Per Cent. | Forgings of Nickel Steel, Oil-tempered or Annealed. Per Cent. |
|---|---|---|---|---|
| Phosphorus shall not exceed .... | 0.10 | 0 06 | 0.04 | 0.04 |
| Sulphur " .... | 0 10 | 0.06 | 0 04 | 0.04 |
| Nickel " .... | .... | .... | .... | 3.00–4.00 |

4. **Bending Test.**—A specimen one inch by one-half inch (1″ × 1/2″) shall bend cold at 180° without fracture on outside of bent portion, as follows:

Around a diameter of 1/2″ for forgings of soft steel.

Around a diameter of 1¼″ for forgings of carbon steel not annealed.

Around a diameter of 1½″ for forgings of carbon steel annealed, if 20″ in diameter or over.

Around a diameter of 1″ for forgings of carbon steel annealed, if under 20″ diameter.

Around a diameter of 1″ for forgings of carbon steel oil-tempered.

Around a diameter of 1/2″ for forgings of nickel steel annealed.

Around a diameter of 1″ for forgings of nickel steel oil-tempered.

TEST PIECES AND METHODS OF TESTING.

5. **Test Specimen for Tensile Test.**—The standard turned test specimen, one-half inch (1/2″) diameter and two inches (2″) gauged length, shall be used to determine the physical properties specified in paragraph No. 3. It is shown in Fig. 639.

6. **Number and Location of Tensile Specimens.**—The number and location of test specimens to be taken from a melt, blow, or a forging shall depend upon its character and importance and must therefore be regulated by individual cases. The test specimens shall be cut cold from the forging or full-sized prolongation of same parallel to the axis of the forging and half-way between the centre and outside, the specimens to be longitudinal, i.e., the length of the specimen to correspond with the direction in which the metal is most drawn out or worked. When forgings have large ends or collars, the test specimens shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged or bored, the specimen shall be taken within the finished section prolonged, half-way between the inner and outer surface of the wall of the forging.

7. **Test Specimen for Bending.**—The specimen for bending test one inch by one-half inch (1″ × 1/2″) shall be cut as specified in paragraph No. 6. The bending test may be made by pressure or by blows.

8. **Yield-point.**—The yield-point specified in paragraph No. 3 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine.

9. **Elastic Limit.**—The elastic limit specified in paragraph No. 3 shall be determined by means of an extensometer, which is to be attached to the test specimen in such manner as to show the change in rate of extension under uniform rate of loading, and will be taken at that point where the proportionality changes.

10. **Sample for Chemical Analysis.**—Turnings from the tensile specimen or drillings from the bending specimen or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in chemical composition specified in paragraph No. 2.

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plan, and shall give necessary main dimensions, thickness and kind of metals, location of foundation bolts, and all important sizes of the machinery as erected.

These general and detailed drawings shall be made on mounted double elephant paper of a size of 25½x39 inches inside the margin lines, strongly and substantially bound in book form, with the name and date of the engines printed in gilt letters on the covers of the book.

All drawings shall be accurately and neatly executed in ink in a workmanlike manner and to an appropriate scale. All sheets shall be uniformly lettered and consecutively numbered and provided with proper titles and headings.

## DESIGN.

### *General Features.*

13. The two engines shall be designed to be erected and operated independently in the south pit of the engine house, which will be built by the city of St. Louis, substantially as shown by the plans on file in the office of the water commissioner. **Pit.**

Especial attention must be paid to the fact that the engines will be used for direct pressure service.

14. Engines shall have ample space around all their various parts for access and maintenance.

15. The height of the water in the wet well will depend upon height of water in conduit, which will be approximately constant. **Suction.**

16. The engines shall be designed for an initial steam pressure of 125 pounds per square inch and a water pressure of 125 pounds per square inch. **Steam.**

17. The pumps shall be designed and constructed to deliver the stipulated quantity of water at a plunger speed which will insure a smooth and effective action of the pump valves, and all working parts of the machinery, but in no case shall the diameter of any pump plunger exceed 40 per cent. of its stroke, or the plunger speed exceed 180 feet per minute. **Plunger.**

18. The arrangement and construction of the engines shall be such that they will give equal steam cards on the up and down strokes. **Balanced.**

Reliability, etc. 19. The engines shall be designed and proportioned to have great working strength, stability and stiffness, and ample space around all parts for erection, repairs, lubrication, inspection and adjustment.

Vertical 20. The steam cylinders and the plungers of the engines shall be vertical.

Height. 21. The steam cylinders and the regulating mechanism of the cut-off and valve motion shall be placed entirely above an elevation of 120 feet above datum.

Frame. 22. The pump chambers and steam cylinders shall be rigidly connected and supported through the intervening frames and columns to make the whole construction of ample stability, strength and stiffness.

Plungers. 23. Each engine shall have vertical, single acting outside packed plungers, and no construction will be allowed requiring internal stuffing boxes, glands or water packings in the pumps. All stuffing boxes shall be readily accessible for inspection and tightening up, while the engine is running.

Removal of Parts. 24. The machinery shall be so constructed, supported and arranged that the pump chambers or any important part or piece of the substructure can be easily removed to such position that it can be hoisted out of the pump pit without necessitating the frame and fixed parts of the superstructure of the machinery being taken apart, disturbed or removed.

Condenser. 25. The two engines shall each be provided with a surface condenser, of appropriate size and construction to maintain a steady vacuum, and designed to directly utilize the water discharged by the main pumps for condensation of the exhaust steam.

Attachments and Appurtenances. 26. The contractor shall furnish and put up all pipes, valves, oil cups, drip pans, fittings and fixtures required to make the construction complete inside the engine room and pump pit, and shall furnish flanges drilled for connection on end of pipes near wall.

Appearance. 27. The various parts of the machinery shall be of plain shapes and forms, adapted to their specific purposes, insuring great strength and reliability with good mechanical effects.

*Frame and Fixed Parts.*

28. The frame and foundation of the engines shall be so designed that changes of temperature can not alter the distribution of the loads on, or affect the alignment of the members of, the frame, and, where necessary, expansion joints shall be used. **Expansion.**

29. The frame of the engine shall be designed to have great stiffness and weight, so that it shall withstand all working stresses with the minimum vibration. All bed plates or sole plates resting on masonry shall have ample bearing surfaces to safely distribute the working pressures. **Frame.**

30. The machinery shall be substantially and securely anchored and held in place with a sufficient number of foundation bolts. **Anchor Bolts.**

31. All castings shall be designed to avoid sudden changes of section and of such forms as will cool uniformly without shrinkage strains. **Castings.**

32. At all flanges of castings there shall be a reinforcement or addition of metal, of at least 30 per cent. of the regular thickness, which shall extend in length or height at least twice the total thickness of the metal at the reinforcement. All flanges to be of not less thickness than the total metal at the reinforcement.

33. All castings must have good sized fillets at all corners; no small brackets will be allowed.

34. If reheaters are used they shall be designed and constructed to be absolutely steam tight under all working conditions to which they will be subjected, and must have proper heating area and space and facilities for examination, repairs and renewals. **Reheaters.**

35. If steam jackets are used they must be secured to the steam cylinder in such a manner as to allow free and easy expansion and contraction, without causing internal leakage of joints or derangement of any description to jackets or cylinders, or undue strains in any part; and must be arranged to insure proper circulation of steam and ready removal of the jacket water. **Jackets.**

36. All flat plates and surfaces acted upon by water pressure must be substantially proportioned and strengthened with a sufficient number of heavy ribs, to make them of ample stiffness and

strength to safely carry the loads to which they will be subjected.

37. All handholes and manholes shall be of ample size, well fitted, and so constructed as to be readily opened and closed.

38. Priming and draining pipes and valves shall be provided for filling and emptying the pump chambers.

**Condenser.**

39. The condensers must safely stand all working stresses to which they may be subjected, without leakage or weakness of any description.

**Examinations and Repairs.**

40. The condensers shall be constructed to give ample facilities and space for the examination, insertion and withdrawal of tubes and packing of joints. The tubes must be provided with perfectly tight and easily removable packings, allowing for expansion and contraction, without injury or leakage.

41. The condensers shall be so arranged that the amount of water passing through, or condensing surface, can be adjusted to suit varying temperatures.

42. Arrangement must be made for proper distribution and circulation of the exhaust steam and condensing water on the cooling surfaces of the condenser, without injurious impingement of the steam or condensing water.

43. All glands and washers used in the condensers shall be made of composition; all bolts and nuts (except stay bolts) used inside the condensers shall be made of Tobin bronze.

44. The condensers must be provided with all necessary auxiliary pipes, valves and tanks.

**Hot Well.**

45. The hot well shall be set at the highest elevation in the pit which the design of the engines will permit.

46. There shall be effectual means and apparatus provided for the separation of grease and oil from the condensed water before it is fed to the boilers.

**Suction and Discharge Pipes.**

47. The suction and discharge pipes shall be thirty inches in diameter.

48. For each engine there shall be a single suction or inlet pipe, which shall be attached to the gate valve, furnished by the city of St. Louis, shown in the plans of the pump pits.

49. The discharge pipe for each engine shall

be carried up to an elevation of 113.6 ft., and then horizontally through and to a distance of two feet from the outside of the pump pit wall, and shall be provided with a drilled flange for connection to pump main.

50. Each engine shall be provided with air vessels of sufficient capacity to insure smooth, easy and equal action of the pumps. **Air Chambers.**

51. Each engine shall be provided with a by-pass pipe, arranged to facilitate draining the pump mains and starting the engines. **By-pass.**

52. Each engine shall be provided with a pressure relief valve designed and arranged to by-pass the discharge of its pumps when the pressure on the pump mains exceeds 125 pounds per square inch. **Relief Valves**

53. The pressure relief to be of sufficient capacity to by-pass total discharge of the engine.

54. There shall be platforms or galleries of cast iron plates or wrought iron open work at convenient locations upon the pump and steam ends, which will allow all of the operations necessary in running and maintaining the engines to be performed with the greatest safety and ease.

55. The contractor shall design, furnish and erect iron stairways, landings and galleries leading from the top gallery down to the bottom of the pump pit, with all intermediate galleries and supporting girders, beams and composition railings required to make them complete and satisfactory in all respects. All of the above to be made of neat and harmonious proportions, and arranged to leave sufficient space for hoisting and removing the pump chambers and other parts of the machinery without disturbing any beams, bed-plates or other stationary parts, or necessitating the removal of stairways, landings or galleries to any great extent.

56. The galleries, stairs and platforms shall be arranged to secure as good diffusion of light down the pump pit as possible. **Light.**

57. The stairs to be made without risers. Tread plates and all gallery plates to be made of a suitable open-work pattern.

All parts of stairs, galleries and platforms shall be accessible for inspection and painting.

*Mechanism and Wearing Parts.*

**Strength and Stiffness.** 58. All moving parts shall be of ample strength and of sufficient stiffness to prevent undue vibrations in operation.

**Wearing surfaces.** 59. All journals and wearing surfaces shall be of sufficient size and of proper proportion to avoid excessive pressure and heating.

**Counter-boring.** 60. When practicable, provision shall be made to prevent the wearing of shoulders on either stationary or moving parts at their extreme travel.

**Journals.** 61. All stationary journals shall have suitable boxes, babbitt lined when necessary, and all journals above four inches in diameter shall have provisions for horizontal and vertical adjustment.

**Bushings.** 62. All glands and guide rings of stuffing boxes shall be provided with composition linings forced in and securely held in place, and the glands shall be cupped out to make proper receptacles for lubricants, leakage water, etc.

**Valves, etc.** 63. The bodies of all valves, three inches in diameter and smaller, shall be entirely of composition, but the bodies of valves larger than three inches, may be of cast iron, with composition valve and valve seats.

64. All valves, fittings, fixtures and appurtenances used, shall be of an approved design.

**Steam End.** 65. The valve motions and starting arrangements of the engines shall be such that each engine can be promptly and safely started and operated by one engineer.

**Valves.** 66. The steam distribution valves shall be of a known reliable type. They shall be well balanced and so designed as to work with the minimum friction, to wear even and steam-tight, and to have proper facilities for refitting and adjustment.

**Valve Motion.** 67. The steam valve mechanism shall be of ample strength and durability, and must be reliable in all its motions and entirely free from any danger of failure, derangement or rebounding. **Regulation.** The engine and valve mechanism to be provided with an automatic device to prevent racing in case of a broken pump main.

**Cut-off.** 68. The engines shall be fitted with a variable cut-off mechanism so arranged as to be easily and

quickly adjusted while the engines are in operation.

69. The running throttle valves of the engines shall be of a well-balanced type and operate quickly and easily under full steam pressure. Throttle.

70. The steam pistons of the cylinders shall be provided with Babbitt and Harris piston packing, packing which, in the opinion of the water commissioner, is equally efficient. Pistons.

71. Steam valves above six inches in diameter shall have steel stems provided with Phosphor bronze nuts.

72. The area of the suction and discharge valves shall be sufficient to insure proper filling and discharging of the pumps under all conditions, but in no case shall the total suction valve area, or the total discharge valve area of each engine be less than 6 square feet. Pump End.

73. The valves shall be designed and constructed to open and close promptly and quietly, shall be tight and of ample strength, and shall be especially designed for facility of repairs and renewals. Valves.

74. All valve stems of stop and gate water valves shall be made of Tobin bronze.

75. All connecting, piston, plunger and distance rods, and all movable parts must be of ample strength and stiffness to withstand all working stresses. Connecting Pieces.

76. The piston rods, plunger and plunger rods, and all reciprocation parts have properly designed guides and crossheads. The crossheads shall have shoes adjustable for wear. Guides.

77. All journals and pins of connecting and valve rods, and of all reciprocating and oscillating rods, shall have well proportioned strap or box ends having easily removable composition boxes, Babbitt lined where required, and provided with wedges, keys or bolts for adjustment of wear. Each link or connecting rod shall at the different ends, have provisions for compensation of wear in the same direction. Boxes.

78. All strap or box ends shall be of a shape having great strength and stiffness, holding the composition boxes securely, and giving a neat and workmanlike appearance.

**Locked Nuts.** 79. All nuts of pillow block caps bolts and follower bolts of pistons, all screw joints of moving parts and all keys shall be provided with a secure locking device.

**Fly Wheel.** 80. If a fly-wheel is used, the shafts shall rest in pillow blocks very securely and rigidly supported at ample distances apart.

**Air Pumps.** 81. The construction of the air pumps must be such that they will at all times perform their work promptly without noise or injurious shocks.

82. The air pump and all accessory pumps required to run the engine, except the boiler feed pump, shall be driven from the main engine.

## MATERIALS.

83. All materials used throughout this construction must be of the special class and grade called for in the specifications and designated in drawings, and shall in each case fully stand the specified tests.

**Castings.** 84. All castings shall be free from blow holes, flaws, scabs and defects of any description, and shall be smooth, close grained, sound, tough and of true forms and dimensions.

85. All casting must be done in accordance with the best modern foundry practice to obtain castings of the very best quality. Castings above 500 pounds in weight shall be moulded in dry sand or loam. Great care must be taken to make all castings as nearly as practicable of uniform thickness throughout.

86. No plugging or other stopping of holes or defects of castings will be allowed.

**Cast Iron.** 87. The cast iron used in the steam cylinders, the steam distribution valves, the barrels of air pumps and the water plungers shall be close, fine grained, hard and uniform in character and of good wearing qualities. The cast iron used in all other parts of this construction shall be of superior quality, tough and of even grain, and shall possess a tensile strength of not less than 22,000 pounds per square inch. Test bars of the metal 2 inches by 1 inch, when broken transversely, 24 inches between supports and loaded in the center, shall have a breaking load of not less than 2,200 pounds, and shall have a total deflection of not less than 0.35 of an inch before breaking.

88. The test bars shall be cast as nearly as possible to the above dimensions without finishing, but corrections will be made by the water commissioner for variations in thickness and width, and the corrected results must conform to the above requirements. **Test Bars.**

89. If any two test bars, cast the same day, show a tensile strength less than 22,000 pounds per square inch, or do not show the required cross breaking load or deflection, all the castings made from the melting from which the samples were taken may be rejected.

90. All steel castings used in the construction shall be thoroughly annealed and possess a tensile strength of 65,000 to 75,000 pounds, and 15 per cent. elongation in two inches. **Steel.**

91. All steel forgings used in this construction shall be equal to forgings manufactured by the Otis Steel Company, Cleveland, Ohio, and have a tensile strength of not less than 75,000 pounds per square inch of section, and show an elongation of 20 per cent. in eight diameters.

92. All of the wrought iron used shall be tough, fibrous and uniform in character, and specimens broken in the testing machine shall show a tensile strength of not less than 50,000 pounds per square inch, with an elongation of 18 per cent. in eight diameters. **Wrought Iron.**

93. If any specimen of steel or wrought iron shall not conform to the above requirements, all material of the lot from which the specimen was taken, will be rejected.

94. The water commissioner may take at random any wrought iron bolt and nut, and have it broken in a testing machine. If any two bolts shall not fill the above stipulated requirements for wrought iron, the whole lot of that size and make may be rejected; the effective area used in computing the breaking strength, will be the area corresponding to the smallest diameter at the bottom of the threads, when cut in accordance with the U. S. standard. **Bolts.**

95. Rivets shall be made from the best refined iron, and must be capable of being bent cold until the sides are in close contact without sign of fracture on the convex side. **Rivets.**

Shapes. 96. All rolled wrought iron shapes shall be free from twists, bends, seams, blisters, buckles, cinder spots or imperfect edges. All sheet and plate iron must be capable of being worked at a proper heat without injury.

Rods. 97. All rods shall be formed in one continuous rolled or forged piece without weld.

Composition. 98. All the composition metal used [excepting for Tobin bronze and hand railing] shall consist of the best quality, new material only, of mixtures specially adapted for the work in each case, and approved by the water commissioner.

Phosphor Bronze. 99. All Phosphor bronze used must be homogeneous and uniform in character, and shall have a tensile strength of not less than 30,000 pounds per square inch, with an elongation of 15 per cent. in eight diameters.

Tobin Bronze. 100. All Tobin bronze used must be homogeneous and uniform in character, and specimens broken in a testing machine shall show a tensile strength of not less than 60,000 pounds per square inch, and an elongation of 20 per cent. in eight diameters.

101. Finished bolts and nuts of Tobin or Phosphor bronze may be tested in the same manner as specified for wrought iron, and if any two bolts shall not fulfill the requirements, the whole lot of that size and make will be rejected.

Test Bars. 102. Test specimens and samples of castings, forgings, composition or any other material used in this construction, shall be prepared ready for testing and supplied in the number, shape, finish and sizes required by the water commissioner, and shall be prepared as may be directed at any time during the pouring or working of the materials.

For all material taken by the water commissioner for testing, the following prices will be paid, which shall include the cost of preparing and finishing the test specimens, viz.:

For all wrought iron or steel, the sum of ten cents per pound.

For all composition, the sum of thirty cents per pound.

For all cast iron, the sum of three cents per pound.

All broken material to belong to the city of St. Louis.

103. The Babbitt metal used throughout the construction must be of the following approximate proportions by analysis: 88 per cent. pure tin, eight per cent. antimony, and four per cent. Lake Superior copper. **Babbitt Metal.**

104. All rubber for valves and gaskets must be of a suitable quality, approved by the water commissioner before it is used. **Rubber.**

105. All other material used in the engines and not mentioned in these specifications will be subject to inspection, test and approval by the water commissioner before it is used. **Other materials**

CONSTRUCTION.

106. The workmanship and finish of the pumping engines throughout shall be equal to the best American practice, and in every respect satisfactory to the water commissioner. **Workmanship**

107. All surfaces worked in machine tools must be true and smooth, and accurately conform to the drawings in shape, size and alignment. **Machine Worked.**

108. The bearing surfaces of all sole and bed plates and parts resting on masonry shall be planed.

109. If fly-wheels are used, the parts shall be fitted and fastened together in the most careful and workmanlike manner and the outer circumferences and the sides of the rim shall be turned smooth and true.

110. All joints of bed plate and frame to be planed or faced and carefully fitted. **Joints.**

111. The steam cylinders shall be bored in a vertical position, perfectly smooth and truly cylindrical, with a boring bar of proper diameter. **Boring.**

112. All circular flanges shall be faced on the outer circumference. **Turning.**

113. All centers of lathe work must be made of ample size and carefully preserved.

114. All corners in journals and elsewhere in turned work shall be rounded to proper radii.

115. All steam joints shall be made in an approved manner, with a very thin gasket of Jenkins' Usidurian packing. **Joints.**

116. All water joints to be made with rubber or paper gaskets, arranged with special care to prevent blowing out.

117. All seats of steam and water gates must be scraped and ground tight.

**Journals.** 118. All journals to be turned straight, cylindrical and smooth. Particular attention and care shall be paid to the proper fitting and scraping of all journal boxes, to make the same of an extraordinarily good bearing surface, and accurate fit to their housings or carrying members.

**Straps, etc.** 119. Straps, gibs, keys, reamed bolts and boxes of all connecting rods must be fitted with the utmost care and accuracy, and finished in a thorough and workmanlike manner.

**Scraping.** 120. The final fitting marks shall, for all parts, be preserved for examination and must in all cases be satisfactory to the water commissioner.

121. All journal boxes, pins, keys and other details of the machinery shall be taken apart at any time during the process of fitting or erecting, when the water commissioner so directs, to allow a thorough examination of fit and workmanship.

**Gear.** 122. If gear wheels are used in the valve motion of the engines, they shall be properly designed and accurately cut in gear cutting machines.

**Cam Treads, etc.** 123. The treads of cams and other parts of the valve motion subject to intermittent or sudden motion and heavy wear shall be of tempered steel or case hardened iron.

**Tempering or Hardening.** 124. The tempering or hardening processes must be so conducted that parts will retain their proper size and shapes and have the requisite hardness.

**Centering.** 125. All parts of the engines must be well secured and correctly centered with accurately fitted dowel pins, reamed bolts or male and female joints.

**Bolting.** 126. All flanges must be cast solid, and all bolt holes shall be drilled with perfectly sharpened and centered twist-drills to insure accurate round holes.

**Dowel Pins.** 127. All dowel pins must be of proper taper, and well fitted; and where necessary, shall have proper facilities for removal.

128. All holes intended to receive tapering parts shall be carefully reamed and ground and the tapering parts driven or forced into place. **Taper.**

129. Nuts and bolts and all threads shall be of the U. S. standard, except where special threads are necessary. **Threads.**

130. The threads and shanks of all bolts above 5/8 inch in diameter shall be cut and turned in the lathe, and the ends of all bolts shall be finished to a neat conical or hemispherical point.

131. The resting surface for nuts and heads of all bolts shall be faced to present a smooth, plane surface, square to the axis of the bolt.

132. Case hardened, finished and polished nuts shall be used in all exposed work above the upper floor level, and also for all parts requiring frequent removal and adjusting. All other nuts and boltheads above the upper floor level, and nuts for all stuffing boxes, and at such other places as may be necessary, shall be finished. **Finished Nuts.**

133. Finished Phosphor bronze nuts and rolled Tobin bronze studs and bolts to be used for all fastenings inside the pump chambers, and for all glands of stuffing boxes of the pump end.

134. Cold pressed nuts shall be used for all stationary parts of the pump chambers, and in all cases where not otherwise specified. **Cold Pressed Nuts.**

135. All nuts and bolt heads shall be hexagonal in shape and must be faced on top and bottom. The sides shall fit their wrenches accurately. **Hexagonal.**

136. All key-ways and keys must be accurately fitted and properly driven or forced into place, and must be of appropriate size and taper. **Keys.**

137. All riveted work shall be specially designed for its particular uses, and executed in a thorough and workmanlike manner.

138. All riveted joints subject to pressure shall be thoroughly and neatly calked with a round-nosed tool. **Calking.**

139. All connecting rods, links and valve rods shall be draw-file finished. **Finishing.**

140. All bright and specially finished work must be of the highest grade and entirely free from scratches, specks and flaws.

141. All visible composition work shall have a bright finish.

142. All exposed machine worked surfaces of

all parts above the upper floor level and of all moving parts, except fly-wheels, shall have a bright finish.

**Lagging.** 143. The steam cylinders, steam chests, reheaters, steam and distribution pipe and other heated surfaces of the machinery, when necessary, shall be protected by neat mahogany or walnut lagging, securely fastened and held in place by brass bands and button-headed brass screws, or by bright finished false covers.

**Covering.** 144. All steam pipes and heated surfaces shall be protected with approved non-conductors to the depth of flanges.

145. The material to be used in covering steam pipes, cylinders, reheaters and all protected parts, and the method of its application, shall be subject to approval by the water commissioner.

146. No non-conductors, lagging or false covers shall be applied until the construction has been thoroughly tested by working steam pressure and all leakages and defects developed have been thoroughly remedied.

## ERECTION.

**In Shop** 147. The contractor shall erect in the shop such parts of the steam and water ends of the engines as may be necessary, in order that the final erection can be carried on with despatch in a thorough and workmanlike manner.

**Transporting** 148. The contractor shall, at his own expense and risk, transport all parts of the machinery to the pumping station, but will be allowed the use of the power traveling crane in the engine house for erecting.

**Masonry.** 149. All foundations and piers required for the support and anchorage of the engines, in addition to that shown in the city's drawings, will be built by the city of St. Louis, to drawings furnished by the contractor. All foundation piers will be built of first-class coursed cut stone masonry and provided with granite capstones of appropriate sizes, and charged to the contractor at $20 per cubic yard.

**Wall Boxes, etc.** 150. The contractor shall deliver at the pumping station all bolts, washers, wall boxes, girders, etc., intended to be inserted in the masonry, in

ample time to prevent delay during the building of the foundation walls and piers.

151. The contractor shall be responsible for the proper and exact location of all parts, when placed in accordance with his drawings and templets.

152. The contractor shall do all work necessary to erect, fit and secure the engines in the pump pit upon the foundation piers as completed and built by the city of St. Louis. **In Pit.**

153. Every sole plate, girder, bed plate and casting resting on or secured to masonry, shall be provided with a rust joint of sufficient thickness, carefully driven and packed and consisting of ingredients satisfactory to the water commissioner. **Rust Joint.**

154. Great care shall be taken in the erection of the engines to place and secure the various sole and bed plates upon solid, plane and smooth bearings. All joints between stationary details must be made with the utmost accuracy and precision, insuring perfect and permanent alignment. None of the parts shall be unduly strained in lining up. **Bearings.**

155. The contractor shall so conduct his operations as not to interfere with the work of other contractors, and the disposal of his tools and materials during storage and erection will be subject to the approval of the water commissioner. **Other Work.**

156. The party of the second part will furnish and set the gate valves of the suction pipes, but the contractor shall pump out all accumulated water in the pump pit before commencing erection, and do all necessary pumping during erection of engines. **Water**

157. All finished parts must be well protected in shops and during transportation to prevent injury and abrasion. **Protection of Parts.**

158. All injured parts must be replaced, when in the judgment of the water commissioner, refitting will not suffice. **Damage.**

159. The contractor shall remove all staging used in erecting the engines, and leave the pump pit, engine room and premises neat and clean. **Cleaning up.**

160. The contractor shall, at his own cost, make good all damages to masonry, buildings, or other property of the city of St. Louis, occasioned by **Damage to Masonry, etc.**

the contractor or his employees in the transportation and erection of the machinery.

Storage of Machinery Parts. 161. The city of St. Louis will furnish space within its premises for the reception of the various parts of the machinery, but shall not be responsible for the safe keeping of these parts, nor for damage caused to them from exposure or other cause.

PAINTING.

162. All castings and details must be inspected and approved before painting, and in no case shall the paint or pitch be applied until all surfaces are trimmed and thoroughly cleaned.

Paraffine Varnish. 163. All unfinished iron work not visible from the engine room floor (except where otherwise required) and that above the floor intended to be encased, shall be thoroughly painted inside and out with three coats of No. 1 paraffine varnish, applied hot. The first coat shall be put on at the shop, and the others after erection, excepting for inside surfaces of pumps, pipes, etc., which shall receive two coats at the shop and one after erection.

Oil paint. 164. All unfinished iron work visible from the engine room floor, shall be thoroughly cleaned, rubbed down and painted with four coats of a good quality of paint and strictly pure linseed oil. The first coat shall be put on at the shop and the others after erection.

165. The paint shall be of a grade and color approved by the water commissioner, and shall be applied, striped and varnished to his satisfaction.

166. All parts to be covered by non-conductors must be thoroughly cleaned and freed from rust, and painted with three coats of paint of a kind, color and quality to be determined by the water commissioner before application of the non-conductors.

Finished Iron Work. 167. All finished and polished surfaces must be kept entirely free from rust until erected and finally accepted.

TESTING.

Pressure. 168. After erection has been completed, and before the final painting, a blank flange shall be

bolted on the out-door end of the discharge pipe, and the whole construction tested with hydraulic pressure. A force pump shall be connected to the discharge pipe, and a pressure of 200 pounds per square inch applied in such manner as to test the pumps, pump valves, air vessels, discharge pipes, pump rods and the frames of the engines. After this test the engine is to be run to full capacity, discharging through the pressure relief valves for the purposes of testing same; a further test to be made by suddenly opening gate on pump main to test speed controlling device mentioned in section 67.

These tests must be conducted by the contractor with great care and in a manner satisfactory to the water commissioner.

The contractor shall furnish all labor necessary, and all piping, cocks, valves, gauges, force pumps, flanges and appliances required in the tests.

169. For the purpose of determining the duty of the engines furnished under this contract, there shall be an expert duty test of twenty-four hours continuous run for each engine. These tests shall be conducted by three experts, one to be selected by the water commissioner, one by the contractor, and the two thus named to select the third. **Duty Test.**

The duty tests shall be conducted for one engine at a time, unless otherwise ordered by the water commissioner.

170. The water of condensation from all steam jackets and reheaters shall be gathered and its weight carefully determined, and it shall be charged against the engines during all of the duty tests.

171. The total weight of water fed to the boilers during the tests shall be considered the amount of steam used when corrected for entrainment exceeding two per cent.

172. Steam used for running the boiler feed pumps during the duty tests will not be charged against the engines.

173. The twenty-four hours' duty test shall be made with the water in the wet well at an approximate elevation of 110, and shall be conducted by the experts selected in accordance with section 169 of this contract. **Expert Test.**

**Speed.** 174. If, in the opinion of the water commissioner, the speed of the engines at any time during the twenty-four hours' test is such as to jeopardize their safety, he shall have the right to order them run at such reduced speed as will give a smooth and quiet action.

**Head (h).** 175. The head (h) to be inserted into the formula for computing the duty of the engines during the running test, shall be ascertained by attaching a gauge to the discharge pipe close to where it turns into and runs through the foundation walls of the pit, and by the elevation of the water in the wet well.

176. Any part or detail of the engines showing undue strain or weakness of any description, must be replaced, and all defects developed in these tests shall be corrected by the contractor to the entire satisfaction of the water commissioner.

ADDITIONAL APPLIANCES.

**Wrenches.** 177. The contractor shall furnish for all sizes of bolts a complete set of wrenches for each engine, accurately fitted to the respective sizes of nuts. The wrenches for all finished nuts about the engines shall have a bright finish and shall be marked with their respective sizes.

178. Each engine shall be provided with one steam gauge, graduated from 0 to 250 pounds, one vacuum gauge, one suitable steam gauge on each receiver (if such be employed in the construction), and one engine revolution counter; all of them to have brass cases, triple silver plated, and placed convenient for observation. The dials of gauges to be ten (10) inches in diameter.

179. Each of the air vessels of the pumps shall be provided with one glass water gauge of satisfactory design. The hot well for each engine shall be provided with a suitable, permanently attached thermometer of appropriate design.

**Indicators.** 180. The contractor shall furnish one steam indicator for each steam cylinder and three indicators for the main pumps, and one indicator for the air pumps. The indicators shall be the Thompson, Crosby or Tabor.

181. Each steam cylinder, main and air pumps of the two engines shall be provided with permanent piping, fixtures and motion appliances for

attaching and working the indicators. All valves, cocks, pipes and appliances for the attachment of the indicators to the steam cylinders and pumps shall be made of composition, of ample size and complete in every respect.

182. All journals must be provided with sight-feed oil cups. There shall also be brass drip pans or pockets at all journals and oiling places to catch lubricants. Oil Cups, etc.

183. The steam cylinders shall be fitted with sight-feed lubricators.

184. There shall be valves, pipes and drip pans at all places where necessary, for receiving and conveying water from stuffing boxes, etc.

185. The contractor shall furnish an extra set of suction valves and an extra set of discharge valves with all parts complete.

REPAIRS.

186. Near the end of the year of probation, the water commissioner will make examination of the engines, and any part or detail found to be defective or injured through excessive wear, overstrain, bad material or faulty design, shall be replaced by the contractor, at his own cost and expense, to the satisfaction of the water commissioner.

The said part of the first part further agree that all the work contemplated and described in this contract and the foregoing specifications, shall be done in acordance with the general drawings approved by, and on file in the office of, the board of public improvements, and with the detail working drawings submitted to and approved by the water commissioner. It is further agreed that the drawings and specifications form a part of this contract, and that, if any discrepancies appear between any of the drawings and the specifications, or between any of the several drawings in themselves, such discrepancies shall be adjusted by the contractor to the satisfaction of the water commissioner. And it is further expressly agreed that the approval of the general and working drawings shall not in any case relieve the contractor from any of his responsibilities under this contract. G

H The said part of the first part hereby expressly agree that the inspection of materials and workmanship shall not relieve —— —— of any of —— obligations to perform sound and reliable work, as herein described. And the said part of the first part further agree to repair or replace any defective part or piece of the pumping engines during one year from the end of the 24 hours' running test, at his own cost and expense.

And it is further agreed that during the aforesaid year, the water commissioner may make all necessary repairs requiring prompt attention, and that the cost of such repairs shall be borne by the contractor.

I And it is further agreed that any work not herein specified which may be fairly implied as included in this contract, of which the water commissioner shall judge, shall be done by the contractor without extra charge. The contractor shall also do such extra work in connection with this contract as the water commissioner may in writing specially direct, and the price for such extra work shall be fixed by the water commissioner, but no claim for extra work shall be allowed, unless the same was done in pursuance of a written order, as aforesaid.

J The said part of the first part further agree that the work embraced in this contract shall be begun within one week after written notice so to do shall have been given to the contractor by the water commissioner, and continued (unless the said commissioner shall otherwise in writing specially direct), with such force and in such manner as to secure its completion within twenty-six months thereafter, the time of beginning, rate of progress, and time of completion being essential conditions of this contract. And the part of the first part further agree that if the pumping engines to be furnished under this contract are not completed at the time above specified, then there shall be retained by said second party, as ascertained and liquidated damages, the sum of fifty ($50.00) dollars per day for every day thereafter until said engines are ready for service.

K The party of the second part agrees to have the pump pits ready for the commencement of the

erection of the engines within twenty months, and to have the steam ready for testing and running the engines twenty-three months after the date of the above notice to begin work.

And the part of the first part further agree that shall not be entitled to any claim for any hindrance or delay from any cause whatever in the progress of the work, or any portion thereof; but any hindrance or delay occasioned by the party of the second part shall entitle said part of the first part to an extension of the time for completing this contract, sufficient to compensate for the detention, the same to be determined by the water commissioner. L

The said part of the first part further agree that will not sublet the work to be done under this contract, but will keep the same under control, and that will not assign the same by power of attorney or otherwise, and that will at all times have a representative present where any work is in progress under this contract. Whenever it may be desired to give directions, orders will be given by the water commissioner and obeyed by the contractor's representative who may have charge of the particular work in reference to which orders are given. If any person employed by the contractor on the work should appear to the water commissioner to be incompetent or disorderly, he shall, upon the requisition of the water commissioner, be at once discharged and not again employed. M

It is further agreed that if the part of the first part shall assign this contract, or abandon the work to be done under this agreement, or shall neglect or refuse to comply with the specifications or stipulations herein contained, the board of public improvements shall have the right, with the consent of the mayor, to annul and cancel this contract, and to relet the work or any part thereof; and such annulment shall not entitle the contractor to recover damages on account thereof; nor shall it affect the right of the city of St. Louis to recover damages which may arise from such failure. N

And the said first part hereby agree to protect and defend and save harmless the said city of St. Louis against any demand for patent fees O

on any patented invention, article or arrangement that may be used by said first part in the pumping engines furnished under this contract.

P The said part of the first part further agree to indemnify and save harmless the city of St. Louis from all suits or actions brought against the said city on account of injuries or damages received or sustained by any party or parties during the construction of the pumping engines, or by or in consequence of any negligence in guarding the same, or any improper materials used in the construction, or by or on account of any act or omission of the said part of the first part or agents.

Q The part of the first part further agree that each engine furnished under this contract shall have a pumping capacity of ten million U. S. gallons in twenty-four hours. The capacity to be at a speed that will insure smooth and quiet action, and to be determined by the experts during the duty test.

R The part of the first part hereby agree that the pumping engines furnished under this contract shall perform, during a running test of twenty-four hours, a duty of one hundred and twenty-five million foot-pounds per thousand pounds of commercially dry steam.

The part of the first part further agree that in case either engine fails to perform a duty of one hundred and twenty-five million foot-pounds per thousand pounds of steam, during the working test of twenty-four hours, —— —— will pay to the party of the second part, as an agreed measure of damages for lack of efficiency of the engine, in the ratio of $2,500.00 for each one million foot-pounds which the duty falls below one hundred and twenty-five million.

In case either engine exceeds, during the twenty-four hours' working test, an average duty of one hundred and twenty-five million foot-pounds per thousand pounds of steam, the party of the second part agrees to pay to the part of the first part, as a reward for the superior efficiency of the engine, an amount to be in the ratio of $1,000.00 for each one million foot-pounds which the duty comes above one hundred and twenty-five million.

On condition of the true and faithful performance of all the conditions of this agreement and specifications, the said party of the second part agrees to pay to said part of the first part the sum of —— dollars, subject to such additions or deductions as are authorized by the provisions and conditions of this contract, in full payment for all the work and materials, designs and drawings required by this contract, embracing the satisfactory construction and erection of such pumping engines and appurtenances as are herein defined and described in all their parts and requirements. S

Payments on account will be made as follows, viz.:

*a.* On or about the first of each month, the water commissioner shall cause an approximate estimate to be made of the value of the materials and work done, based on the total amount to be paid for the engines; from the amount so found he shall deduct 20 per cent. and all sums previously paid or retained under this contract, and certify the remainder as then due. Provided, however, that nothing herein contained shall be construed to affect the right of the city of St. Louis, hereby reserved, to reject the whole or any portion of the work aforesaid, should the said certificates be found or known to be inconsistent with the terms of this agreement, or otherwise improperly given. T

*b.* When the twenty-four hours' running test shall have been satisfactorily completed, the water commissioner shall make an estimate for the amount of the contract price, less 10 per cent., and all sums retained under this contract.

It is further agreed that the water commissioner shall have charge of and operate the engines furnished under this contract, during the twenty-four hours' duty test, and the year following, and that the part of the first part shall not be relieved or released thereby from any of —— obligations under this contract.

At the end of said year, the pumping engines and appurtenances, if found to be in good working condition, shall be finally accepted, and the water commissioner shall make and certify a final

estimate in favor of the first part and the responsibility of said first part shall then cease.

U The said part of the first part further agree that —— —— shall not be entitled to demand or receive payment for any portion of the aforesaid work or materials, except in the manner set forth in this agreement; nor until each and all of the stipulations hereinbefore mentioned are complied with, and the water commissioner shall have given his certificate to that effect. The party of the second part hereby agrees and binds itself to pay the said part of the first part in cash, the whole amount of money accruing to the said part of the first part under this contract, excepting such sum or sums as may be lawfully retained under any of the provisions of this contract hereinbefore set forth, upon the giving by the said part of the first part to the party of the second part a release from all claims and demands whatsoever growing out of this agreement.

V This agreement is entered into subject to the city charter and ordinances in general. and in particular to the following provisions of article VI., section 28, of said charter, to wit:

"*a.*" The aggregate payments under this contract shall be limited by the appropriations made therefor.

"*b.*" On ten days' notice the work, under this agreement, may, without cost or claim against the city, be suspended by the board of public improvements, with the approval of the mayor, for want of means or other substantial cause. Provided, that on the complaint of any citizen and tax payer, that any public work is being done contrary to contract, or the work or material used is imperfect or different from what was stipulated to be furnished or done, the said board shall examine into the complaint and may appoint two or more competent commissioners to examine and report on said work, and after such examination, or after considering the report of said commissioners, they shall make such order in the premises as shall be just and reasonable, and what the public interests seem to demand, and such decision shall be binding on all parties. The cost of such examination shall be borne by

the contractor, if such complaint is decided to be well founded, and by the complainant if found to be groundless.

Ordinance 16,514, approved December 22, 1891, is hereby made part of this contract, and must be observed in all its provisions, namely: W

SECTION 1. All contracts hereafter entered into wherein the city of St. Louis is a party, for the doing of any kind of work or labor for the city of St. Louis, including work on all public buildings, works and enterprises, shall contain the following terms and conditions: (*a*) That the men, persons or laborers who may be employed in the doing, prosecuting, or accomplishment of such work done by the contractor with the city of St. Louis, or any one under him, or any person controlling the said men, persons or laborers, shall not be required to work more than eight hours a day; (*b*) That in case of the violation of such provisions of such contracts, the mayor shall immediately declare such contracts canceled and forfeited, and the work being done under such contracts shall be relet in the manner provided for the letting of such work, and such contractor shall thereafter be ineligible to bid upon such work under such reletting, and the difference in the cost of doing such work under such contract so canceled and forfeited, and under such reletting, shall be sued for on the bond of such contractor so violating such contract.

*For the faithful performance* of all and singular the terms and stipulations of this contract, in every particular, the said —— —— part of the first part, as principal, and —— —— as securities, hereby bind themselves and their respective heirs, executors and administrators, unto the said city of St. Louis, in the penal sum of —— dollars, lawful money of the United States, conditioned that in the event the said —— —— shall faithfully and properly perform the foregoing contract according to all the terms thereof, and shall as soon as the work contemplated by said contract is completed, pay to the proper parties all amounts due for material and labor used and employed in the performance thereof, then this obligation to be void, otherwise of full force and effect, and the same may be sued on at the in-

stance of any material man, laboring man or mechanic, in the name of the city of St. Louis, to the use of such material man, laboring man or mechanic, for any breach of the condition hereof; provided, that no such suit shall be instituted after the expiration of ninety days from the completion of said contract.

In witness whereof, the said —— —— part of the first part, as principal, and —— —— securities, parties of the first part, have hereunto set their hands and seals respectively, and the city of St. Louis, party of the second part, acting by and through the board of public improvements aforesaid, have subscribed these presents the day and year first above written.

WITNESS:

—— ——

—— ——.

—— —— [seal].
—— —— [seal].
—— —— [seal].
—— —— [seal].

The city of St. Louis by —— ——,
President Board of Public Improvements.

Countersigned: —— ——,
Comptroller.

CITY COUNSELOR'S OFFICE.
St. Louis, ——, 18—.

The foregoing agreement and bond are in due form according to law.

—— ——,
City Counselor.

MAYOR'S OFFICE.
St. Louis, ——, 18.—

I hereby approve of the securities to the foregoing contract and bond.

—— ——,
Mayor.
M. L. H.

**171. Complete General Specifications for Water Tubular Boilers and Settings.** The following complete general specifications for horizontal water tubular boilers were used in connection with the engine specifications given in the previous article, and the contract was let under similar contracting, gen-

eral and surety clauses. These portions are omitted from these specifications for the sake of brevity. They were prepared by the same gentleman who prepared the specifications in the last article, and are thought to represent an equally good practice:

1. The work to be done consists in furnishing designs and plans, material, tools and labor, and building, transporting and erecting complete in place, ready for firing, in the boiler-house at Bissell's Point, eight horizontal water tube boilers, the boilers to be provided with all necessary valves, gauges, breechings and connection to underground smoke flue.

DESIGN.

2. The boilers to be of the type designated as horizontal water tube boilers, designed and built with special reference to easy access for cleaning and repairing of both internal and external surfaces. The boilers to be designed for natural draft of present smoke stack. No stays or obstructions of any kind shall be placed inside of the water tubes.

3. The boilers to be designed for a working steam pressure of 140 pounds per square inch, with a factor of safety of six on minimum sections.

4. Each boiler shall have a total tube heating surface of not less than 3,000 square feet, and a grate area equivalent to 75 square feet of straight grate.

5. The boilers to be provided with smoke preventing furnaces, which shall effectually stop smoke while burning southern Illinois coal at a rate of from twenty (20) to twenty-five (25) pounds per square foot of grate per hour. The furnace shall be some well tested and approved device for prevention of smoke, which does not use a steam jet or a system of brick arches in the fire box.

6. The boilers to be set in four independent batteries, as shown on drawing, each boiler to be provided with walls, settings, valves, gauges, smoke breeching and dampers necessary for operating or repairing independently of other boilers.

7. The fire fronts shall be designed to facili-

tate firing and removing ashes. The fire doors to be of suitable design to secure the regulation of air admitted to the fire, and prevent radiation through the fire door openings during regular service. The boiler dampers to be arranged to regulate from front of boiler.

**Fittings.** 8. Each boiler to have an eight-inch stop valve, admitting of independent connection to main steam pipe.

To each boiler there shall also be attached, besides the eight-inch stop valve, two three and a half inch improved pop safety valves, placed in such positions that their escape pipes will not interfere with the roof trusses or sky-lights of the boiler house.

9. All steam drums to be made of steel plates of the quality hereinafter specified.

10. The boilers to be set and supported in a manner admitting of expansion and contraction of the same, without injury to the brick work or boilers in any way.

All beams required to support or carry the boilers to be of ample strength, and must be either wrought iron or steel.

There shall be central air spaces in all walls enclosing the boilers.

## FITTINGS AND APPURTENANCES.

11. The contractor shall furnish and put in place all necessary valves, steam gauges, water glass gauges, safety valve escape pipes, and all appurtenances, and make connection to steam main, feed and blow-off pipes and underground smoke flue.

**Wrenches.** 12. For all nuts on the boilers and fittings, there must be furnished well-fitted wrenches.

**Steam Gauges and Plugs.** 13. The steam gauges shall be attached to the boiler fronts with nickel-plated brass siphon pipe and cocks, in a neat manner, admitting of easy removal.

The feed-water valve of each boiler to be provided with a suitable arrangement for its regulation from the front of the boilers.

Steam gauges to be brass case, nickle-plated, fourteen inches in diameter, maximum pressure 250 pounds, five-pound divisions.

14. Each boiler to be provided with three Bailey's safety copper cap fusible plugs, or other safety plugs of equally good manufacture and satisfactory fusibility.

15. There shall be suitable copper spouts and polished brass piping wherever visible, to catch the steam and water from the gauge cocks and glass water gauges, and they shall be piped and connected to the ash box in an acceptable manner. **Drains.**

16. Steam valves above six inches in diameter shall have steel stems, provided with phospho-bronze nuts, and the glands of all stuffing boxes shall be of composition. **Valves.**

17. All valves, fittings, fixtures and appurtenances used shall be of the best design.

18. The steam drums and all parts of the boilers and pipes not covered by brick work, and the breechings to be covered with magnesia covering, not less than one and a half inches in thickness, thoroughly secured in place.

19. Hand hole plates must be secured in an approved manner, to insure the greatest possible safety against accidents from breaking of fastenings.

## MATERIALS.

20. All material used throughout this construction must be of the special class and grade called for in the specifications, and shall in each case fully stand the specified tests.

21. All plates in the boilers to be made of steel. **Steel Plates.** The steel plates used in these boilers must be stamped with the maker's name and the tensile strength; to be homogeneous and of uniform quality; to have a tensile strength of not less than 55,000 pounds, nor more than 62,000 pounds per square inch, an elastic limit of at least 30,000 pounds per square inch, and an elongation of at least twenty-four (24) per cent. in eight inches.

Specimens must stand the following bending test, viz.:

To bend double, closing up completely without showing sign of fracture when bent cold, or after having been heated to a cherry red and plunged into water at 70 degrees Fahrenheit.

The water commissioner shall have the right to

order test specimens 2x14 inches, to be cut out of any of the plates to be used in the boilers.

Wrought Iron. 22. All wrought iron for bolts, nuts or other purposes shall be double refined, and have an ultimate tensile strength of at least 52,000 pounds per square inch, an elastic limit of 26,000 pounds per square inch, and an elongation of eighteen (18) per cent. in eight inches.

23. Rivets to be Burden's best, and must be capable of bending cold until the sides are in close contact, without sign of fracture; and iron used for screw stays, stay bolts and braces to be of best quality of American manufacture.

Tubes. 24. Tubes to be lap-welded of the best quality of American manufacture, of a diameter of 3½ inches or 4 inches, and must stand a satisfactory hammer test.

Castings. 25. All castings shall be free from blow holes, flaws, scabs and defects of any description, and shall be smooth, close-grained, sound, tough and of true forms and dimensions.

Great care must be taken to make all castings, as nearly as practicable, of uniform thickness throughout, when not otherwise required.

Iron Castings. 26. All cast iron used under steam pressure shall be of good quality, tough and of even grain, and shall possess a tensile strength of not less than 22,000 pounds per square inch.

Test bars of the metal, two inches by one inch, when broken transversely, twenty-four inches between supports and loaded in the center, shall have a breaking load of not less than 2,200 pounds, and shall have a total deflection of not less than 35-100 of an inch before breaking.

The test bars shall be cast as nearly as possible to the above dimensions, without finishing, but corrections will be made by the water commissioner for variations in thickness and width, and the corrected results must conform to the above requirements.

27. If any two test bars, cast the same day, show a tensile strength less than is required in these specifications, or do not show the required cross breaking load or deflection, all castings made from the melting from which the samples were taken may be rejected.

28. Test specimens and samples of castings and forgings, or any other kind of material used in this construction, shall be prepared ready for testing and supplied in the number, shape, finish and sizes required by the water commissioner, and shall be prepared as may be directed at any time during the pouring or working of materials. Specimens

29. The stamps put upon the steel sheets by the manufacturer must at all times be preserved for identification, and so placed as to be visible on the outside of boilers; if any stamp is cut out in process of manufacture, the water commissioner shall first replace it by a duplicate stamp.

WORKMANSHIP.

30. The best workmanship on these boilers will be exacted, and it must be equal in all respects to that executed in the best boiler works in this country.

31. All holes for bolts, studs and rivets in castings must be drilled. No cored bolt holes will be allowed.

No plugging or other stopping of holes or defects of castings will be allowed.

32. Any rivet which is deformed, cracked, burnt, improperly driven, leaky, or in any way injured, must be cut out and properly replaced.

33. All surfaces of sheets and other parts to be riveted must be brought together to close contact and accurately fitted, with bearing surfaces smooth and clean, and while being riveted to be held firmly in position and alignment without exerting injurious strains upon any portion or detail of the boiler.

34. The use of drift pins, to bring rivet holes to match, or come true and central, will not be allowed in the process of riveting, and must be dispensed with entirely. The utmost accuracy in punching the rivet holes will be exacted. Rivet holes failing to fit, or come fair and true, must be reamed out accurately, and rivets of suitable size used.

35. All sheets of the boilers must be satisfactorily straightened before being planed, bent, flanged, drilled, fitted, etc. Sheets.

36. All scarfing to be done in a neat and work-

manlike manner. Sufficient allowance of material must be made at all places where scarfs are required.

37. The edges of all sheets to be planed to a suitable bevel.

Caulking. 38. All seams to be caulked on both sides where accessible.

All caulking to be done in the best manner, with round-nosed caulking tools; great care to be taken not to mar the sheet or rivets.

Threads. 39. The threads of all studs, bolts, screw stays, stay bolts and nuts, to be chased with great care and skill, to insure uniformity in pitch and accuracy in fit.

All holes which are to receive bolts, screw stays, studs or stay bolts, to be accurately centered, drilled and tapped, to give a desirable fit and tightness of the threads.

The stay bolts, screw stays and studs to be entered, screwed in and riveted in a careful and workmanlike manner, to insure true and parallel surfaces and an equitable distribution of the stress upon all of the sustaining members.

40. All expanding of tubes and nipples shall be done in a careful and workmanlike manner, and shall be absolutely water-tight under the test pressure.

Doors. 41. The fire, ash and cleaning doors to be fitted air-tight to their seating or bearing surfaces.

All holes in the lugs for hinges of the doors used in the construction to be drilled and reamed, to accurately fit the turned pins for same.

42. The brick work must be executed in a thorough and workmanlike manner, the brick used to be strictly first-class in every respect. Outside of setting to be laid with stock brick in white mortar; inside, where exposed to heat, to be lined with best quality fire brick.

43. All red bricks to be laid in mortar of approved quality, and all fire brick to be laid in ground fire clay.

## FOUNDATIONS.

Foundations. 44. The city will furnish complete foundations for the boilers, the position in the house to be as shown on plans on file in the office of the water

commissioner, and the space occupied by each battery of boilers to be not greater than that shown.

GENERAL CLAUSES.

45. The boilers shall be tested by the contractor with a water pressure of 210 pounds per square inch, under which they must be water-tight. Pressure Test.

46. When the boilers shall have been tested to the satisfaction of the water commissioner, they shall be thoroughly scraped, cleaned, dried and painted outside with one coat of linseed oil. Paint

47. The fire front, fire and ash doors and other cast and sheet iron parts, except grate bars, after approval shall be painted in the shop with one coat of paraffine varnish, and after erection they shall receive another coat of the same.

48. The contractor shall, at his own expense and risk, transport the boilers and appurtenances to Bissell's Point, furnish all necessary labor, tools and appliances, and erect the same complete, as above specified. Erection

Every possible and necessary care must be taken in handling and transporting the boilers, to prevent injury of any description to the same.

49. The contractor shall so conduct his work as not to interfere with the operation of any boilers under fire, and the disposal of his tools and materials, during storage and erection, will be subject to the approval of the water commissioner.

50. The contractor shall, at his own cost, make good all damages to masonry, buildings or other property of the city of St. Louis, occasioned by the contractor or his employees in the transportation and erection of the machinery.

51. The city of St. Louis will furnish space within its premises for the reception of the boilers and details, but shall not be responsible for the safe keeping of the same, nor for damage caused to them from exposure or other causes. Storage.

52. The city will remove the old boilers and prepare foundations below the floor line for new boilers, contractors to furnish castings to be set in underground flue for smoke connections.

53. The contractor shall get all finished mate-

rials on the ground at the earliest possible moment, and proceed with the erection of the same as soon as notified by the water commissioner.

The work of erection in place, ready for firing, shall be carried on continuously, night and day, and the contractor shall provide for that purpose three complete erecting gangs.

If at any time during the erection the water commissioner shall be of the opinion that the work can be expedited by the employment of additional labor or tools, he shall order the contractor to make such increase in his working force or appliances as he may deem necessary to secure the most rapid progress possible; and it is especially understood and agreed that if the contractor fails to put the required force at work promptly, that the water commissioner shall employ such labor as he may deem necessary, and charge the cost of the same to the contractor.

54. The contractor shall bear the cost of making all repairs necessitated by defective materials, workmanship or design of the boilers and furnaces for the space of one year after the boilers are put into regular operation. M. L. H.

**172. Specifications for an Engine House.** The following specifications for an engine house differ from those in the two previous articles inasmuch as they were accompanied by complete detail drawings. The contracting and surety clauses are here omitted, since they would be the same as those given in article 170. This engine house covers three large pump pits, designed for three sets of low service pumping engines, and it is entirely without a floor, nearly the entire space being occupied by the pits. The walls rest directly upon the natural rock, and an electric traveling crane is carried by a track near the top of the two side walls, this crane spanning the entire opening and running the entire length of the building. The side walls, therefore, were made very strong and substantial.

**Work to be done.** 1. The work to be done consists in building and finishing complete low service engine house at Chain of Rocks, St. Louis City Water Works Extension. The foundation on which the struct-

ure will rest is now completed. The work is shown in detail on the following drawings:

No. 1. Elevation of side walls.
" 2. Elevation of end walls.
" 3. Longitudinal section.
" 4. Transverse sections.
" 5. Plan below traveler.
" 6. Plan above traveler.
" 7. Gallery plan.
" 8. Roof plan.
" 9. Roof plan for iron trusses.
" 10. Cut stone courses.
" 11. Details of stone-faced door and window openings, terra cotta details.
" 12. Details of cut stone in cornice, fire walls and brick arches.
" 13. Details of windows, doors, ceiling and cast iron door sill.
" 14 Details of large sliding doors and hangers.
" 15. Details of door and window frames.
" 16. Details of sky lights.
" 17. Details of galleries, stairs, ladders, balcony and door sills.
" 18. Details of iron trusses.
" 19. Strain sheet.
" 20. Details of brick cornice, fire walls, etc.

MORTAR.

2. All sand for mortar shall be clean, sharp, coarse Mississippi river channel sand. Sand.

3. All cement used in the masonry shall be H. H. Meier's Puzzolan cement, put up in well-made barrels. Cement.

4. It shall be subject to such tests as may be necessary to fully determine its character, and any cement which, in the opinion of the water commissioner, is unfit for the work herein specified will be rejected.

5. All short weight or damaged barrels of cement, or cement without the maker's brand, will be rejected without test. Samples for testing shall be furnished at such times and in such manner as may be required. On all barrels accepted inspection marks will be placed, and the contractor shall carefully preserve these marks and not allow them to be imitated.

6. All cement for use on the works shall be kept under cover, thoroughly protected from moisture, raised from the ground—by blocking or otherwise—and dry until used. The contractor

shall keep in storage a quantity of accepted cement sufficient to insure the uninterrupted progress of the work.

7. Cement may be reinspected at any time, and, if found to be damaged or of improper quality, will be rejected. All rejected cement shall at once be removed from the line of work.

Mortar. 8. All mortar used in the masonry shall be cement mortar, and shall be made of three parts of sand and one part of cement, each of the quality above specified. All mortar shall be made fresh for the work in hand, and any mortar which has begun to set shall not be used.

Colored Mortar 9. All brick in outer face of walls shall be laid in mortar, colored with a red mortar stain that is even in color and durable, and approved by the water commissioner.

STONE MASONRY.

Granite 10. The base, ashler and water table courses shall be of Missouri red granite, sound, free from discolorations, and of even color. All visible rock face shall be free from drill-holes or tool-marks. Base course and water table shall be six-cut work, ashler course, rock face.

11. Base course shall be 12 inches high, 8½-inch bond, with 4-inch by 4-inch chamfer on top. Ashler course shall be 1 foot 4½ inches high, 13-inch bond on the setting bed and 8½ inch bond on the top bed, and cut for iron anchors. Water table shall be 7½ inches high, 6-inch bond, cut for iron anchors and chamfered on top as shown. The ashler and water table course shall be anchored to the brick backing with tarred wrought iron anchors.

12. All of the granite work shall be laid in the most workmanlike and substantial manner, with even and equal joints, ¼ inch thick. Each stone must have perfect and level beds. All joints shall be pointed well and neatly with pointing mortar, colored red. Pointing joints must show equal size throughout, and be struck with pointing tool and straight edge.

13. Eight stones, 2 feet 0 inches by 15 inches by 18 inches, and ten stones, 2 feet 0 inches by 14 inches by 15 inches, shall be furnished and

set as directed, to be used as bed stones for roof trusses; said stones shall be of granite, sound in all respects, top and bottom beds dressed true and level.

14. Window sills, sill courses, belt course, coping, pediments, range work around door and window openings, and all cut stone work above the water table, shall be of Lake Superior red sandstone; fine Crandall finish, laid with equal and even ¼-inch joints in full beds of mortar. All joints shall be without chipping and beds of stone level and perfect. Spalls shall not be used in leveling any portion of the work. Window sills shall be cut with drips and seats, the seats not being cut to exact size until after the frames are set. **Sandstone.**

15. All the sand stone work shall be cut and set in the very best manner, and the whole cleaned down perfectly, and pointed with red pointing mortar, with concave joints, and backed up as soon as set.

16. The stone must be perfect in all respects, even color, free from all defects or pockets.

17. In cleaning down the work, care must be taken that the joints are rubbed to a level surface.

18. The stone bed course for the track of the crane shall be made of lime stone from approved quarries, dressed smooth on top bed, bush-hammered on face, and with true and parallel beds. This course shall extend the entire length of the building on each side, and it shall be 14 inches wide and 8 inches high, set in a swimming bed of cement mortar. When set same must be leveled *perfectly*, the entire length of the building, taking each side out of wind with the other. Special care must be exercised in cutting and setting this course. See detail sheet No. 20. **Limestone.**

BRICK WORK.

19. All the exterior faces of the walls, jambs, etc., shall be executed with even-colored dark red and hard brick. All other portions of the brick work executed with strictly red and hard quality. Light red brick shall not be used in any portion of the building, nor will salmon or defective brick **Brick.**

be allowed in *any* part of the walls or on the premises.

Face Walls. 20. Brick in exterior of walls shall be laid in red mortar, with even and full bed and end joints, struck with a concave tool, as the work progresses.

Height of Courses. 21. The standard height for laying all brick shall be 2 courses to 5 inches, unless otherwise ordered by the water commissioner.

Thickness of Walls. 22. Figured thickness of walls will govern.

Bond. 23. The brick in every fifth course shall be headers, and face work shall be laid to bond with Flemish bond headers, as directed by the water commissioner, during the progress of the work.

The different courses shall be slushed, and all joints thoroughly filled with cement motar.

All courses shall be laid to a line, front and rear; plumb, true, straight and level.

Brick Arches. 24. All arches shall be turned with arch-brick, ground to proper radiating lines, and the face of same shall be laid, alternately, 8½ inches and 4½ inches, and backed up with row locks laid with shove joint. All jambs shall be returned and neatly pointed. All arches shall be full depth of wall. Turn brick arches over seats of each truss, as shown on sheet No. 18.

How Laid. 25. Brick must be thoroughly wet before laying, if required. Stone walls shall be well swept off and sprinkled with water before any brick is laid on them.

Notches in Foundation. 26. Cut a sufficient number of recesses through the stone foundation walls for passage through same of the copper down-spouts, and build them in with stone work, as shown on sheet No. 1.

27. All frames, anchors, wood, bricks, etc., that are necessary shall be built in.

Setting Cut Stone above Water Table. 28. All cut stone above the water table shall be set, and the walls carefully leveled for the reception of the iron trusses. After the walls are built all sills shall be under-pinned with red mortar.

29. All necessary wood plates for the fastening of tin flashing shall be built in.

Setting Terra Cotta. 30. All terra cotta shall be bonded firmly to the brick work and neatly pointed with red mortar at completion.

31. Two iron I beams shall be built in and covered with a 3/8-inch plate, where shown on sheet No. 3, in the side wall over the traveler off-set and above the circle head windows, leaving the wall open on the under side, so that the traveler can be carried through this opening. After traveler has been set in position the opening shall be closed up with brick work, leaving the I beams in the walls, but not exposed. **Iron I Beams.**

32. All exterior brick walls shall be cleaned of all dirt and mortar stains at completion. **Cleaning Down**

TERRA COTTA.

33. All the terra cotta letters and border around same, on east and west walls, to be hard burned, best quality red, even in color, and of designs and dimensions shown, free from "flashing" or warping. **Quality.**

34. The letters shall be first modeled and a plaster mould made, and from the mould the letters shall be pressed. **Moulds.**

35. After terra cotta has been burned it shall be laid out and carefully fitted and shaded and trimmed if necessary, after which each piece shall be lettered to correspond with a setting plan which shall accompany the delivery of all terra cotta. The details for the terra cotta will be found on sheet No. 11. **Fitting.**

36. All terra cotta to be set in putty, colored to match, and properly bonded to the brick backing. The bricklayers shall set all terra cotta. **How Set.**

COPPER WORK.

37. Four 10-inch square down-pipes, 16-ounce copper, to lead water from roof and connect same with sewer, shall be furnished in place. Each down-pipe shall have square copper head of 20-ounce copper, and moulded copper bands of double thickness of 16-ounce copper placed not more than 4 feet apart, and secured with 3-inch copper holdfasts, with rosette heads. **Down-Spouts.**

38. Gutters shall be formed with roofing tin of form and size shown on drawings for same, and constitute a part of the roof-covering, and graded so as to carry the water from the center to the four corners of the building and open into the copper down-spouts. Tin gutters shall be **Gutters, etc.**

carefully flashed and counterflashed into the brick fire-walls, and nailed to wood strips provided for said flashing, as provided for in clause No. 44.

Finials. 39. The copper finials for the skylights shall be furnished and secured in place.

Drip. 40. Copper drip strips, 1¾ inches wide, 1 inch to project into the mortar joint, and ¾ inch to be exposed and bent to an angle of 30 degrees, as shown on detail sheet No. 12, shall be furnished the bricklayers on the scaffold.

TIN.

41. The roof shall be covered with roofing plates, standing seam, with joints well tacked, anchored and soldered, using rosin as a flux, and 8-pound soldering coppers, and tin well and closely cleated to roof.

Tin Plate. 42. The roofing plate used shall be Scott's IX extra coated American roofing tin plate, and must bear a coating of not less than 36 pounds to the box, and must be fully guaranteed, with the maker's name stamped in each sheet, and each sheet must be coated in perfect uniformity and free from "wasters."

Gutters and Flashing. 43. The gutters shall be lined with Scott's IX roofing tin, flat seam, and shall conform to the gutter plan as shown on sheet No. 8, and shall be carefully flashed against the brick fire-walls, and be firmly nailed to the wood flashing strips, after which all of this gutter flashing must be well and carefully counterflashed.

44. The wood flashing strips shall be built into the brick fire-walls 8 inches above the wall edge of gutter at center of roof and 24 inches above at each of the four corners.

Skylight Flashing. 45. The flashing around the skylights shall extend against and 8 inches up the wood skylight frame, and shall be finished before the carpenter lays the base.

Paint and Paper. 46. Tin shall be painted, before being laid, with two coats of the best quality of iron oxide, ground in pure linseed oil, on the under side, and must be perfectly dry before laying; and that part of the roof covered with tin shall have two layers of heavy straw building paper laid over sheathing boards before putting down the said tin. Each layer of paper to overlap and be fastened down

smooth and flat, and to be kept free from moisture. (See clause No. 51.)

### LUMBER.

47. All the lumber used in the construction of the building shall be graded as follows:

Purlins—4-inch by 10-inch, yellow pine, long leaf, surfaced three sides and stub moulded. **Carpenter Work.**

Lower Roof Sheating—1½ inches by 4 inches, tongued, grooved and beaded on under side, "B" select, surfaced one side.

Upper Roof Sheathing—⅞ inch by 8 to 10 or 12 inches No. 1 ship lap, surfaced one side.

Skylight Frame — Posts and plates, 5½ in. x 5½ in. yellow pine No. 1.
" " Rafters, 4 in. x 4 in. yellow pine No. 1.
" " Nailing girths, 2 in. x 6 in. white pine No. 1.
" " Outside casing, ⅞ in. "B" select.
" " " base, 1½ in. "B" select.
" " Inside casing, ⅞ in. "B" select.
" " " lining, ⅞ in. x 4 in. beaded white pine, "C" select.
" " Plinth and base blocks, 1½ in. "B" select

Flashing strips — 2 in. x 4 in., No. 1 white pine.
1st gallery floor girders.—3 in. x 8 in. and 2 in. x 6 in. No. 1 long California yellow pine, surfaced three sides.
1st gallery floor.— 1½ in. x 3 in., first and second yellow pine, tongued and grooved.[1]
Tread board — 2 in. x 12 in. white oak. **Mill Work.**
Window frames — "B" select.
Sash — "A" select.
Doors — "B" select.

48. All lumber must stand *strictly* on grade, kiln dried, free from large loose knots, sap. shakes, rot, stain or any other defects foreign to their respective grades. **Quality.**

### CARPENTER WORK.

49. The roof shall be covered with two courses of sheathing. The lower sheathing shall be white pine, tongued, grooved and beaded, and shall be 1½ inches thick by 4 inches wide; under side dressed and smoothed at the bench to a perfect smooth surface, and fastened to place and left free from hammer-marks or other defects. Upper **Roof.**

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[1] There is no floor proper in the building — only a narrow gallery around the sides. AUTHOR.

sheathing shall be 7/8 inch by 8, 10 or 12 inches wide, No. 1 ship lap, laid diagonally, and nailed to the lower sheathing. Care must be taken that nails shall not go through the lower sheathing; the nailing to be in the purlins.

50. All purlins shall be 4 inch by 10 inch long leaf yellow pine, surfaced three sides, stub moulded, dry, sound and straight grained. They shall be spaced on centers, as shown on detail sheets Nos. 18 and 9, and secured to upper cord of truss by angles and bolts, as detailed.

51. Cover the entire roof with two (2) layers of heavy straw building paper, laid over the ship lap sheathing before putting down the tin. Each layer of paper to overlap and be fastened down smooth and flat, and to be kept free from moisture. This work shall be performed by the carpenter, under the direction of the tinner, and laid in such sections only as required to keep in advance of the tinners. The upper sheathing, paper and tin shall be laid as fast as the lower sheathing is nailed in place, so as to protect the ceiling at all times from the weather.

Skylights. 52. Skylights shall be three (3) in number, and framed in accordance with details for same, as shown on sheet No. 16 (this sheet shows details for the two end lights only; the center light shall be of same construction, but of sufficient length to reach the distance of two truss centers, as per longitudinal elevation and roof plan). The principal posts shall be of 5½ inch by 5½ inch yellow pine, and shall be fastened to purlins with wrought iron anchor straps firmly bolted to both purlins and posts. The upper end of all posts shall be tenoned.

53. Wall plates shall be 5½ inch by 5½ inch yellow pine, and mortised to fit the post tenons, and all fastened together with strap iron anchors and bolts.

54. The hip rafters shall be made of 4 inch by 4 inch yellow pine and dressed four (4) sides, and shall be backed same as for wood sheathing, and upon the top of plates between heels of rafters spike a triangular strip of wood secured rigidly to the plate to receive the thrust of the skylight bars. The center cage shall have the necessary

rafters shown on sheet No. 8, and be firmly bolted at apex through a ridge piece of 2 inch yellow pine, top edge of ridge beveled.

55. Nailing girths shall be 2 inch by 6 inch white pine, No. 1, and be firmly spiked to the framing.

56. The outside shall be cased up with 7/8 inch "B" select, to form the finish above the base. A baseboard of 1 1/2 inches thick, "B" select, beveled on top edge, shall run around the entire frame and be firmly nailed to the casing. See clause No. 45.

57. The inside shall be trimmed by casing up the posts with 7/8 inch thick "B" select, fluted and nailed on plinth and base blocks as shown. The inside below the window stool shall be ceiled with 7/8 inch x 4 inch beaded "B" ceiling, nailed on diagonally, with the nails countersunk and finished at the bottom with a 2-inch band mould.

58. (For specifications of skylight roof, see clause No. 112.)

59. The roof ceiling shall be finished by running a mould along the truss and purlins, forming the different panels, as per detail sheet No. 13. **Ceiling.**

60. The floor of lower gallery shall be made of 1 1/2 inch by 3 inch tongued and grooved first and second yellow pine in continuous lengths. It shall be blind nailed to girders and the nailing joist. **Gallery Floor.**

61. The nailing joist shall be 2 inch by 6 inch No. 1 long leaf yellow pine, and in continuous lengths from bracket to bracket and bolted to channel bar.

62. The floor girders shall be 3 inch by 8 inch No. 1 long leaf yellow pine, surfaced three sides, notched on brackets. All joints shall rest on brackets.

63. The carpenters shall furnish all centers and templets, and shall put up and take down same. The centers and templets shall be made in a proper manner, strong and well braced. **Centers, Templets, etc.**

64. The carpenters shall set all frames, and verify their plumb after the brick arches are turned. **Frames.**

MILL WORK.

Window Frames

65. Window frames below the traveler shall be solid frames for top and bottom pivoted sash, and shall be made of form and dimensions called for by the drawings. The lumber used in their construction shall be clear, dry and sound Wisconsin white pine, "B" select, free from knots or sap. Faces of all frames shall be moulded as per detail.

66. All frames shall be given a heavy coat of paint all around, including back of jambs, and shall be set perfectly plumb; and the sill shall rest on a bed of cement mortar, ¼ inch higher on the inside, so as to make a water tight joint. Casings, mullions, transoms, etc., shall be moulded as shown on details. The frames shall be put together in a strong manner, well and closely nailed, and the stop-beads fastened with 1⅛-inch blued round-headed screws. All the lumber in frames shall be Wisconsin white pine, "B" select, as above specified.

67. The frames shall be provided with moulded stool, terminating with mould against plaster. Mullions and jambs shall be cut down square on stone seats.

68. Stiles, heads, mullions and transoms shall be solid. All circular portions of frames shall be worked in the solid and put together with white lead, so as to break joints throughout, and firmly spiked. A 2 inch by 4 inch bond strip shall be spiked to all frames (except the two door and the two large window frames), extending from sill to spring of arch for anchoring same to brick backing. The heads of frames shall have wood blocks of 2 inch by 4 inch by 8 inch nailed to same and spaced a distance of 18 inches on centers.

69. The two door and window frames above mentioned shall be anchored to the brick backing with wood blocks of bone dry white pine 4 inch by 12 inch by 12 inch, built in the brick work, and spaced as shown on detail sheet No. 11. The frames shall be bolted to same with ¾ inch by 8 inch lag screws. The frames shall fit in a recess of one inch in the brick work.

70. Inside mould and stools will not be nailed in place until plastering is perfectly dry.

71. Two iron dowels shall be placed in the bottom of each jamb and mullion. The dowels shall be of 1-inch round wrought iron, and sunk 1½ inches in stone sill.

72. All frames above the traveler shall be solid frames for side pivoted sash and for 13-inch walls, and shall be made of "B" select.

73. All window sashes shall be of the form and dimensions called for by the drawings. The lumber used in their construction shall be clear, dry and sound Wisconsin white pine ("A" select), free from knots or sap. Sash.

74. All sash shall be moulded and rebated 2¼ inches thick, and divided into lights as shown. Each sash shall be neatly fitted and properly hung with Wollensak's plain bronze sash centers, No. 144, and shall be secured with bronze cupboard turns, and provided with casement rods or shutter holders. No. 8,020, p. 1876, "Simmons."

75. All transom sash that are fixed shall be closely fitted and secured in place with heavy coat of white lead in the stop joints, so that all joints shall be water tight.

76. Skylight sash shall be 2¼ inches thick, and divided as shown on sheet No. 16, center pivoted and made water tight.

77. The door frames at each end of the building shall have rebated solid plank frames, beaded and moulded on outer face to match window frames. They shall be built in same manner as specified for window frames, using "B" select, and shall be secured to brick work in the same manner as specified for other frames. The frame for the double door, south end, shall be rebated for 2¾ inch doors, and shall have a transom bar 3⅞ inches thick. The single door at north end shall be made without transoms and shall have 1¾ inch rebate. Door Frames.

78. The doors at the south end shall be double, and each door shall be hung with four 6 inch by 6 inch real bronze butts, rebated at center joint and beaded. Doors.

79. The doors shall be 2¾ inches thick and made of dry "B" select, with stationary sash divided in lights as shown; lower portions of the doors shall be paneled and moulded as shown by detail sheet No. 13; the panels shall be made of tongued and grooved ⅞ inch "B" select, 2 inches wide, with all joints beaded and driven up in white lead.

80. The single door in the north end shall be made of "B" select, 1¾ inches thick. It shall have stationary sash panels, and be built as specified for south door.

81. Doors shall be secured with mortise locks, rebated for double doors, bronze knobs, plates and trimmings, and flush spring bolts, top and bottom of real bronze.

82. The sash in all doors and transoms for same shall be as specified for the window sash, and the transom sash pivoted and hung with the same kind and quality of hardware.

83. The large sliding doors shall be made of the same quality of lumber as specified for the small doors, and in two thicknesses of 1⅞ inches each, making a total of 3¾ inches, framed separately, and put together with white lead, and firmly screwed up with 3 inch screws, countersunk; they shall have tenoned stiles, rails and muntins; all tenons shall be double pinned with ½ inch white oak pins, and all shall be bolted together with iron rods, as shown by dot lines on detail sheet No. 14. The panels shall be made of tongued and grooved "B" select, 2 inches wide and beaded both sides.

84. Small swing doors shall be framed into each large door, making four in all. They shall be hung with three (3) 4 inch by 4 inch real bronze butts, and fitted with Yale mortise locks, with keys to pass.

85. Each pair of the large sliding doors shall have wrought iron drop bars, made of 2 inch x ¾ inch iron, bolted at one end and made to drop into a hook at the other; with a turned iron hand lift as shown on detail sheet No. 14.

**Oak Brace Frame for Large Doors**

86. An oak brace frame for each door opening, having form, size and radius as shown on detail sheet No. 14, rounded on each edge, shall

be secured to the brick work with expansion bolts, in the most substantial manner, and framed into a girder made of 1¾ inch by 7½ inch oak, of length equal to the run of both doors, and firmly bolted to the wall with bracketed bolts, as detailed. All to be put in position before plastering, in the most careful and substantial manner.

HARDWARE.

87. The numbers and pages given for hardware refer to Simmons' catalogue. Windows.

88. All pivoted windows shall be hung with Wollensak's plain bronze sash centers, No. 144, and secured with plain bronze cupboard turns, No. 8,535, page 1650, and real bronze casement stays, No. 8,020, page 1876. Pivoted transoms shall be fitted with similar sash centers, and with Payson's solid grip transom lifts, real bronze, ½ inch by 6 feet, No. 0336.

89. All doors, except large sliding doors, shall be hung with butts, and fitted with Yale mortise locks and keys to pass, and top and bottom bolts for the double doors. Doors.

90. The two double doors in south end shall each be hung with four 6-inch by 6-inch real bronze butts, and fitted with rebated mortise Yale lock, plain bronze, for 2¾ inch door, with keys to pass, and real bronze extension flush bolts, plain, same as Yale pattern No. 788E., B. 34, page 1675.

91. The single door in north end shall be hung with four 6-inch by 6-inch real plain bronze butts, and fitted with lock for 1¾ inch door of same kind as specified for double door.

92. The four small swing doors that are built in the large sliding doors shall each be hung with three (3) 4 inch by 4 inch real plain bronze butts, and fitted with lock as specified for the north door.

93. The finish of all hardware shall be real plain bronze throughout, and all locks shall be Yale, with keys to pass. Finish.

94. Construct for the two sets of large sliding doors a hanger and track as per detail sheet No. 14. The hanger shall be made of wrought iron 11 inches wide and ¼ inch thick, bent to Iron Work for Sliding Doors.

correspond with profile shown, and fitted with a steel track wheel, turned with a groove, and necessary bearings. The hanger shall be firmly bolted to the doors with heavy screw-bolts, as shown.

95. The track for above hanger shall be made of steel Z bars, 4.72 pounds per foot (Carnegie catalogue, No. 295), with the short flange ground to fit groove in wheel, and the large flange firmly bolted to oak girder. The track shall be equal to the run of both doors. These doors must be made to run easily and work perfectly.

PLASTER.

96. The side and end walls from the stone foundation to the top of the brick walls in the inside of the building, including window-jambs and stools, shall be plastered with Acme plaster, and given a granulated finish with white sand, applied according to the directions of agent. All walls shall have straight, true surfaces, angles plumb, jambs and stools plastered. Walls shall be laid off to represent stone courses, as directed. Joints shall be marked off when plaster is green, and shall be ¼ inch throughout, and cut with clean edges, the joints to continue around window-jambs and to be struck to represent arch stones over openings.

97. A plaster base and wainscot moulding shall be made around the building of height shown, base 12 inches by 1 inch, chamfered on top; wainscot cap, 5 inches by 1 inch, moulded and chamfered top and bottom, as shown on sheets Nos. 3 and 4.

PAINTING AND GLAZING.

98. The contractor shall furnish all material and perform all labor necessary for the proper painting of the building. All sap, knots, etc., of the wood-work shall be covered with a good coat of strong shellac before priming.

Priming 99. All wood-work to be painted shall be primed with French ochre and boiled linseed oil, and all iron-work shall be primed with oxide of iron and boiled linseed oil. All holes and cracks in the wood-work shall be puttied and stopped on the priming coat, and again before applying the last finishing coat.

100. All outside wood-work, usually painted, shall have four (4) coats of pure white lead, ground in linseed oil, and mixed with pure boiled linseed oil. The exterior of all frames, doors, sashes, sky-lights, etc., shall have the last two (2) coats in colors, as directed by the water commissioner. **Outside wood-work.**

101. All tin and galvanized iron shall have, after completion, three (3) coats of Dixon's Silica Graphite paint, thinned with pure boiled linseed oil; each coat shall be allowed to dry thoroughly before the next is applied. Each coat of paint on the tin roof must be of a different shade, and each shade shall be approved by the water commissioner. **Tin and Galvanized Iron.**

102. All of the inside wood-work, including sash, doors and frames, etc., shall be painted four (4) coats of pure white lead, ground in oil, and mixed with pure boiled linseed oil, brushed on smooth and even, and grained a perfect oak on the last coat, after which it shall receive a heavy coat of coach varnish, evenly flowed on and left in the gloss. **Inside Wood-work.**

103. The ceiling, including purlins, skylights, etc., shall be painted with four (4) coats of paint of quality specified above, and of such colors as the water commissioner may direct, and each succeeding coat must be of a different shade, as per direction of the water commissioner. **Ceiling**

104. The first gallery floor shall receive four (4) coats of pure boiled linseed oil, and the floor girders shall be painted to match the iron channel bar and brackets. **Wood Floor.**

105. All iron and steel work before leaving the shop shall be thoroughly cleaned from all loose scale and rust, and after inspection be given one good priming coating of pure, raw linseed oil and iron oxide, well worked into all joints and open spaces. **Iron work.**

106. In riveted work the surfaces coming in contact shall be painted before being riveted together. Bottoms of bed-plates, bearing-plates and any parts which are not accessible for painting after erection, shall have two coats of paint.

107. After the structure is erected the iron work, both wrought and cast, shall be thoroughly and evenly painted with three additional coats of

paint, of quality specified for the wood-work, mixed with strictly pure linseed oil, and each succeeding coat shall be of a different shade, and each shade must be determined and approved by the water commissioner.

Workmanship. 108. The painter must see that all wood-work is perfectly clean before priming or painting, and putty up all nail heads and other defects, and sandpaper smooth and perfectly prepare all wood before applying a second coat. The whole of the painting work throughout to be done in the best and most workmanlike manner, and all paint and varnish spots must be cleaned off the glass, walls and galleries at the completion of the work, and all left clean and perfect, without exception.

109. All paint must be mixed at the building, and under the direction of the water commissioner, except the priming for the iron work.

Glazing. 110. All of the glass throughout shall be American, double thick, perfectly free from any blemish, flaw or defect. All shall be set in oil putty, carefully tacked with tin glazing tacks, and back puttied.

111. All glass to be cleaned after glazing, and again after painting sash.

SKYLIGHT ROOFS.

Manufacture. 112. The skylight roofs used on this building shall be of the Vaile & Young patent, and shall be adapted to the wood cage construction, as detailed on sheet No. 16.

Bars. 113. The bars shall be of galvanized iron, except the parts exposed to the weather, which shall be of 20-ounce copper, and the said bars must be rigid enough to support the glass without deflection. The apex shall not be finished to a point, but shall be fitted to the square of the size of the copper finial, and said finial shall fit over the apex and cover all joints. This finial shall be made of 18-ounce copper and furnished with the skylights.

114. All bars not resting on rafters shall be wrought iron, encased with galvanized iron.

Gutters. 115. All skylights shall have hanging gutters of 20-ounce copper, with a fall to one corner, and from this corner the water shall be conveyed to the main roof by means of a copper down-spout, which shall be furnished with the skylight.

116. All glass used in the skylights shall be ⅜ inch thick and ribbed. It shall be furnished by the manufacturers of the skylights, and it shall be set with special care, and under rigid inspection, and shall be of a continuous length. **Glass.**

ROOF TRUSSES.

117. The castings shall be made from a superior quality of iron, tough and of even grain, and must conform in shape and dimensions to the drawings. Castings must be clean and perfect, without flaw or sand holes or defects of any kind. **Cast Iron.**

118. With the exception of the bearing plates, the roof trussing shall be of soft steel throughout. **Soft Steel.**

119. The steel must be uniform in character. The finished parts must be free from cracks on the faces or corners, and have a clean, smooth finish. No work shall be put upon any steel at or near the blue temperature, or between that of boiling water and of ignition of hardwood sawdust.

120. All tests shall be made by samples cut from the finished material after rolling. All broken samples must show uniform fine grain fractures of a blue, steel gray color, entirely free from a fiery luster or blackish cast. Soft steel shall have an ultimate strength of 54,000 to 62,000 pounds per square inch; an elastic limit not less than 30,000 pounds per square inch, and a minimum elongation of 25 per cent. in 8 inches.

Before or after heating to a light yellow heat and quenching in cold water, this steel must stand bending 180 degrees to a curve, whose inner radius is equal to the thickness of the sample, without sign of fracture.

121. Specimen pieces of a size and form suitable for the testing machine shall be cut from any plate, angle or bar, when directed by the water commissioner.

122. If any specimen shall not conform to above requirements, all the material of the same form and manufacture as the piece from which this specimen was taken will be rejected.

123. All rivets shall be made of soft steel, and the steel for rivets must, under the above bending test, stand closing solidly together without sign of fracture.

**Specimen Bars.** 124. For all material taken by the water commissioner for testing there will be added to the final estimate the following prices, viz.:

For all steel, the sum of five cents per pound.

For all cast iron, the sum of three cents per pound.

All broken material to belong to the party of the second part.

**Finish.** 125. The workmanship and finish throughout shall be thorough and of the very best, and any piece or part, however perfect it may be in other respects, if defective in workmanship, will be rejected.

**Planed.** 126. That part of the bed plate on which rests the three eighth inch bottom plate of the truss shall be planed or faced to a true plane surface. All abutting joints in top and lower chord shall be planed or faced.

**Punching.** 127. In punching rivet holes, the diameter of the die shall in no case exceed the diameter of the punch more than one-sixteenth inch, and all holes must be clean cut, without torn or ragged edges.

**Rivet Holes.** 128. All rivet holes shall be so accurately spaced and drilled or punched that when the several parts are assembled a rivet one-sixteenth inch less in diameter than the hole can be entered hot into any hole without straining the iron by drifting. Occasional variations shall be corrected by reaming.

**Rivet Work.** 129. Whenever possible, all rivets must be machine driven. The rivets, when driven, shall completely fill the holes. The rivet heads shall be round and of a uniform size throughout the work. They shall be full and neatly made, and be concentric with the rivet holes, and thoroughly pinch the connected pieces together. The several pieces forming one built member must fit closely together, and when riveted shall be free from twists, bends or open joints. The angle irons forming the top chord must be bent at the different panel points to the proper angle. The lower chord shall have sufficient camber to allow for the deflection of the loaded truss.

**Bolts and Nuts.** 130. All bolts and nuts to be made from the best quality of soft steel. The nuts to be hexagonal and the heads square. Heads, nuts and threads to be standard size. All bolts shall have a washer under the heads or nuts, where in contact with wood.

131. All rods with screw ends shall be upset at the ends so that the diameter at the bottom of the threads shall be one-sixteenth inch larger than any part of the body of the bar. **Upset Ends.**

132. All the angles, filling and splice plates must fit at their ends to the flange angles sufficiently close to be sealed, when painted, against the admission of water, but need not be boat finished. **Angles, etc**

133. To support and hold purlins in place, short pieces of angle iron 3½ inches by 6 inches by ¾ inch shall be riveted to principals with two ¾-inch rivets, and purlins shall be fastened to them by ¾-inch bolts. The contractor shall furnish all bolts, each with one cast iron washer. **Fastening and Supporting Purlins.**

134. All the bed plates under fixed and sliding end must be fox-bolted to the masonry with 1¼ inch bolts. The contractor must furnish all bolts, drill all holes and set bolts to place with cement. **Bed Plates and Anchors**

IRON GALLERY, LADDERS, ETC.

135. The galleries shall consist of three different sections, as follows:

1st. A lower or first gallery. (Sheet No. 7.)
2d. An upper or second gallery. (Sheet No. 7.)
3d. A balcony gallery. (Sheet No. 4.)

Details for above galleries will be found on sheet No. 17.

136. The first gallery shall extend around the entire building on a level with grade (El. 115), and shall consist of brackets, railing, chains, posts and wood floor. **First Gallery.**

137. The wood floor shall be 4 feet and 2 inches wide and made of 1½ inch thick by 3 inch wide yellow pine flooring, and shall rest upon two girders and one channel bar, and both girders and channel bar shall be supported by cast iron brackets. The channel bar shall be 6 inches high, weighing 9½ pounds per lineal foot, and to this channel shall be bolted yellow pine nailing joists 2 inch by 6 inch; the bolts shall be ⅜ inch, with round head, nuts and washers, and shall be spaced three to each panel. The two yellow pine girders shall be 3 inch by 8 inch and notched so as to seat on the top of brackets.

138. Brackets shall be cast, according to detail, shown on sheet No. 17, and shall be firmly bolted to the stone-mason work with 1 inch by 10 inch expansion bolts, at top and bottom of

each bracket. The stone walls must be recessed sufficiently to give an even bearing for the backs of all brackets.

139. Railing shall be made of gas pipe and suitable fittings connecting same, made in accordance with details. Top and bottom rails shall be 1½ inch and 2 inch gas pipe; intermediate rails, 1¼ inch gas pipe; principal posts 2½ inch, and intermediate posts 2 inch diameter cast iron.

140. At the angle where the stairs commence this first gallery shall be constructed, on a radius, as shown on gallery plan, sheet No. 7, to make room for said stairway. A round hole must be made in this floor to suit stair column.

141. Suitable chain fastening gates shall be provided at all openings in gallery with suitable hooks, etc., chain to be of wrought iron ½ inch in diameter. There shall be two chains at each opening. See sheet No. 7.

**Upper or Second Gallery.** 142. The second gallery shall extend across south end of building, and terminate at one end with a spiral staircase, and shall consist of brackets, channels, railings, post and floor. The brackets shall be cast as per detail, shown on sheet No. 17 (scale, ¾ inch), and fastened to brick work by an expansion bolt at the foot and a bearing plate at the head. Upon these brackets shall rest a six inch channel bar weighing 9½ pounds per lineal foot, and another bar of same size and weight shall be fastened to the brick work by expansion bolts. Upon these two channels the cast floor plates shall take their bearing. The railing, posts, etc., shall be made the same as specified for the first gallery. For a plan of this second or upper gallery, refer to sheet No. 7. The floor plates shall each be cast with three ribs; said ribs shall be spaced on centers, according to the length of the floor plates, and shall be located, one on each extreme edge and one in the center; all 3 inches deep and 1 inch thick.

**Stairs.** 143. Winding stairs shall consist of cast iron center column, treads, rail and newels.

144. The center column shall be cast ⅞ inch metal and be 7 in. in diameter, terminating at upper end with a newel, as shown on sheet No. 17.

145. The center column shall be supported by two 12 inch steel I beams, 42 pounds per foot, located diagonally across one corner of the stone

foundation, with bolts and separators, and set in place before commencing the brick work. The column shall have a square iron flange on the lower end of 1 inch metal, and said flange must be firmly bolted to the steel I beams.

146. Steps or treads shall be cast without risers, but shall have thimble height of step, cast on each step, with tread nosing continued around.

147. These thimbles shall have freedom figured on drawing, and the vacant space shall be well and thoroughly calked with sulphur.

148. Steps shall be cast of ¾ inch metal, diamond pattern tread. Each step-thimble, bracket and flange shall be cast in one piece, each step being bolted to the next at connections. The first risers shall be housed into the wood floor, if necessary.

149. Stair rail shall be made of 2 inch gas pipe, bent to proper sweep and curve, terminating top and bottom at newels. Newels shall be cast iron ⅝ inch metal. All shall be executed according to drawings, each and every portion put up, bolted and secured in the strongest and most workmanlike manner, and to the satisfaction of the water commissioner.

150. The third or balcony gallery shall be constructed of wrought iron brackets, made of ½ inch by 2 inch metal, and fastened to the brick work with expansion bolts. It shall be provided with an oak tread board. This tread board shall be furnished by the carpenter and put in place by the gallery contractor. **Balcony Gallery**

151. This balcony shall extend across north end of building, as shown on section plan No. 4.

152. Two wrought iron ladders with ½ inch by 2 inch sides and ¾ inch round rungs, passing through side pieces and riveted, shall be furnished, put in place and properly secured. One ladder to start on the first or lower gallery and extend up and through the balcony gallery as per drawings. One ladder shall be located on the exterior of the building and commence about 10 feet from the ground and extend upwards to and be anchored into the fire-wall coping, as shown on elevation sheet No. 1. The details for these iron ladders will be found on sheet No. 17. **Ladders.**

153. There shall be cast and set in place cast iron door sills for the doors in the north and south ends and the two large doors in each side. **Door Sills.**

154. Sill for the south door shall be 5 feet 8 inches long and 3 feet 4¾ inches wide, ¾ inches thick, and cast in diamond pattern, with door saddle and seats for wood frame drilled for ½ inch expansion bolts.

155. Sill for the north door shall be 3 feet 6 inches long and 3 feet 4¾ inches wide, cast same as specified for south door.

156. Sills for the large doors shall be cast diamond pattern, 1 inch thick, and shall have a square flange on outside and inside edge as shown. These sills shall be cast in three separate sections, as shown and figured in sheet No. 17.

**Hand Rail.** 157. A hand rail made of 1¼ inch gas pipe shall be provided and put in place and continued along both sides of the building its entire length, 3 feet 6 inches above the traveler I beam. This railing shall project from the wall 6 inches, and be firmly bracketed to the wall at sufficient intervals to insure ample stiffness. The ends shall be secured to the wood window frames. See sheet No. 3.

**Traveler Track.** 158. The traveler track shall consist of an iron I beam, 8 inches in height, and weighing 34 pounds per lineal foot, Carnegie catalogue, No. 8 C, page 22, extending the entire length of building on each side. It shall be firmly bolted to the stone sill course with ¾ inch expansion bolts, and the space between the web of beam and sandstone sill shall be filled with hard burned brick, laid in the best of cement mortar.

159. Upon the top flange of this 8 inch I beam a flat top steel rail, weighing 52 pounds per lineal yard, shall be bolted, extending the entire length on both sides of the building. This rail must be drilled in each flange, and these flanges bolted with ¾ inch bolts into the flanges of the I beam. The rail shall be connected at joints with fishplates and bolts.

**I Beams in Side Walls.** 160. Two 8-inch I beams, weighing 34 pounds per foot, with bolts and separators, shall be built in brick work, as shown on plan and specified in clause No. 31, and covered with a ⅜-inch iron plate.

GENERAL CLAUSES.

**Finish Complete.** 161. All of the materials and work required for the full completion of the building herein specified, to the entire satisfaction of the water

commissioner, shall be furnished and done by the contractor, and should anything not mentioned within this specification be necessary to fully complete the work, the same shall be furnished and done without extra charge.

162. No masonry work of any description shall be laid in freezing weather, except with special permission of the water commissioner. **Frost.**

163. All unfinished work shall be properly protected from injury by frost.

164. Any masonry work found damaged by frost shall be taken down and rebuilt at the cost of the contractor.

165. When the work is completed, the building, substructure and surrounding grounds shall be cleared of all rubbish caused by construction, and left in a neat and presentable condition for immediate use. **Cleaning up.**

166. Measures shall be taken by the contractor, whether required by city ordinance or not, to insure the safety of the public, by such precautions of fencing, watching, lights, etc., as the exigencies of the case may call for. **Public Safety.**

167. The contractor shall furnish, at his own cost and expense, all necessary centering and scaffolding, and remove same at the completion of the work. **Erection.**

168. Due facilities must be afforded the water commissioner for giving the lines, grades and points, and all stakes or marks given by him must be preserved undisturbed.

169 The contractor shall keep on the work, accessible at all times, the plans furnished him by the water commissioner, and a copy of these specifications.

170. At all times, when work is in progress, there shall be a foreman or head workman on the grounds.

171. Necessary conveniences shall be constructed for the use of the contractor's employees, and during the progress of the work herein specified the contractor shall not use or interfere in any manner with the present buildings, pipes or appurtenances of the waterworks.

172. The use of the railroad tracks and switches belonging to the waterworks will be permitted to the contractor for the work herein specified at such times only as will not interfere with the delivery, switching and handling of coal cars.

173. Particular care must be exercised in the protection of all finished work as the building progresses, such as exterior projections, cut stone, iron stairs and galleries, etc., which must be fully protected from injury or defacement during the erection and completion of the building.

174. The erection shall be carried on in such manner as will in no way interfere with the erection, completion and operation of the pumping engines or machinery. The extra cost of handling the erection in this manner must be included in the sum bid for the work.

175. The directions of the water commissioner as to the disposition of building materials and location of sheds, temporary buildings, etc., must be strictly observed.

Examination of work.

176. Whenever required by the water commissioner, the contractor shall furnish all facilities and labor to make an examination of any work, complete or in progress, under this contract. If the work so examined is found defective in any respect, or not in accordance with this contract and specifications, the contractor shall bear all expenses of such examination and of satisfactory reconstruction. If the work so examined is found to be in accordance with the contract and specifications, the expense of the examination and reconstruction will be estimated to contractor at a fair price, to be determined by the water commissioner. M. L. H.

**171. General Specifications for Railroad Concrete Work.** Cement concrete masonry, either with or without reinforcement with steel bars, is coming into such general use that a stone masonry specification in former editions of this work is here replaced by a general specification for railway concrete construction (not reinforced by steel rods), these being now in use (1902) by the Illinois Central Railway Company.

### FOUNDATIONS AND EXCAVATION.

1. *Cofferdams,* where necessary as a protection against water in adjacent streams, etc., shall generally be built in accordance with detailed plans to be furnished in connection with each piece of work. Such cofferdams may consist of substantial or lighter structures in accordance with the amount of protection required or the risk to be incurred.

A—The more substantial cofferdams shall be built by driving rows of piles, spaced from three to five feet apart, centers; these to be securely connected together by lines of horizontal waling bolted on the outside, and sheet piling to be driven outside of these waling pieces and spiked or bolted to them as may be necessary. The sheet piling may consist of two rows of plank, the outer covering the joints between the inner planks —each row driven separate—or they may consist of a combination pile, made up of three pieces of plank, so built together as to make a tongued and grooved structure. In extreme cases, two rows of piles and two rows of sheeting would be used and a "puddling" of clay, or other suitable material, filled in between the two rows of the cofferdams.

B—Except in exposed situations piles may be omitted, and rows of sheet piles secured to waling timbers and properly braced, may serve the purpose of the cofferdam. In all cases all material for the cofferdam shall be furnished by the contractor, and shall be paid for by the lineal foot of pile furnished and driven, and thousand feet B. M. of timber, boards and planking used in the work; these prices to include bolts, spikes and all iron work required to hold same in place.

C—Generally such portions of cofferdams as do not obstruct the free flow of the water and are below ordinary low water may be left in the work. Portions of cofferdams extending above this level will generally be removed, and the cost of such removal is to be included in the prices named by the contractor for this work.

It must not be inferred by the contractors that cofferdams are not deemed necessary because not shown on the general or detailed plans. The contractor shall take up the question of their construction with the proper engineering authority, who shall determine the extent of cofferdam (or sheeting), bracing, etc., required, the work being constructed and paid for as described in other portions of the specifications.

2. Excavation—Either inside of cofferdams or in open pits, shall be taken down to such depth as may be specified by the engineer in charge. The contractor shall be prepared to sheet the sides of such excavation where cofferdams are not used, and to put in proper bracing to protect the same from caving; all timber and plank used for such sheeting to be paid for at the rates named for cofferdam material.

A—All excavated material shall be placed where it is available for filling, either in adjacent embankments, or around the masonry when completed; and such back filling as may be required against abutments, arches, etc., and which can be done

with the excavated material, shall be done by the contractor, and shall be covered by the price paid for excavation.

B—No allowance shall be made on account of slope to sides of excavations where the same are made in material already compacted, the contractor being expected, as above specified, to carry down the excavation to the proper depth, and to protect the same by sheeting and bracing. Where excavations are required to be made in loose or uncompacted material (including sand or sandy soil), the engineer in charge shall make a proper allowance for slope in such material, and shall measure all material removed in making such slope, as a portion of the excavation. The price paid for sheeting, bracing, etc., is to include the whole value of the material, the same being left in the work, if necessary, either as a mold for the concrete foundation, or as a protection against caving, during the process of excavation or of putting in the concrete.

C—If the contractor deposits any excavated material where it will obstruct the water-way or ditches adjacent to railroad embankments, or in any place not fully approved by the engineer in charge, he shall, at his own expense, remove the same before the completion of the work, and place it as may be directed by the engineer, or if the same is not done promptly upon the request of the engineer or inspector in charge of the work, it may be done by the railroad company's employees, and charged to the contractor and deducted from his estimates.

D—Excavation shall be classified as follows:

*a.* Dry excavation, including all materials which can be handled without pumping, and with which no water is mixed.

*b.* Wet excavation, including all material removed from cofferdams or pits, where pumping is required, or where water accumulates, either by seepage or from floods occurring during the progress of the work. The price paid for wet excavation is intended to cover the cost of all pumping which may be required, and shall include furnishing such pumping machinery as may be necessary for the work.

Where there is a rock foundation within reasonable distance below the surface of the ground, the excavation shall be carried down to the rock, and the surface of the same shall be roughly leveled either throughout the whole area of the foundation, or by making steps or benches at different elevations, separated by vertical risers; all loose rock, shale, clay, mud, etc., being removed before putting in the foundation concrete. Should water enter freely along the surface of the rock, the foundation may be prepared in sections, the concrete being filled in upon the rock surface, as each section is prepared for the same.

Care shall be taken that no clay, mud or earthy matter adheres to the rock or to the vertical joints between separate concrete sections, the object being to make a monolithic mass of the whole foundation, and to have the same cemented firmly to the rock.

*c.* Rock excavation, which shall include all solid rock, blasted or otherwise removed from the foundation, or all boulders or pieces of loose rock, weighing over fifty (50) pounds each.

CONCRETE MATERIALS.

3. Concrete Materials may be classified as follows:

A—*Crushed Limestone,* which shall be made by crushing tough, hard, clean limestone and screening same through two-inch meshes or holes.

The Engineer or Inspector in charge shall reject crushed limestone which may have any of the following defects:

*a.* Containing more than one (1) per cent. of earthy or clayey matter.

*b.* Containing more than twenty (20) per cent. of fine stone or stone dust, less than one-half (1-2) inch in size.

*c.* Containing more than five (5) per cent. of soft or rotten limestone which can be crushed or powdered up in the fingers.

*d.* Containing more than ten (10) per cent. of flat stone larger than two (2) inches in greatest dimension.

*e.* Containing more than fifteen (15) per cent. of crushed stone larger than specified (passing through a two (2) inch mesh), unless there be an equal amount of fine material less than one-half (1-2) inch size.

*f.* If any of the five classes of defective stone above named can be modified by mixture with additional material or by breaking large stone by hand, its use may be permitted under the direction of the Engineer or Inspector in charge.

*g.* The use of clean gravel in place of not more than one-half (1-2) of the specified amount of crushed limestone may be permitted at the option of the Chief Engineer, or his authorized representative; but the work shall be done under such special instructions as shall be given in each individual case, depending on the quality of the gravel used and other existing conditions.

B—*Crushed Granite.* This shall generally be used of two sizes: a fine crushed granite, to be used as a substitute for sand, and a coarser size, particles of which are not larger than three-fourths inches in greatest dimensions, and to be used as a substitute for crushed limestone in making bridge seats, pedestal stones, etc. All crushed granite shall be clean, entirely free from dust and earthy or clayey matter, and each grade shall

be of practically uniform size. This material shall always be handled on platforms or plank, or in some way kept entirely free from admixture of earth, sand, etc.

C—*Sand for concrete* shall consist of clean, sharp sand ("pit" or "bank" sand being preferred), and sand shall not be rejected if containing occasionally pieces of small gravel. A sand is preferred which will not pass through a sieve having thirty meshes to the inch. Sand shall be free from earth or alluvial matter; and, when tested by stirring with water or by rubbing in the hands, shall not show the existence of more than one-half of one per cent, of loam, clay or earth. No sand shall be used for the outside finish of any concrete which contains small particles of coal or of lignite, although sand of this character may be accepted for foundation concrete, or for the interior portion of any heavy piece of concrete work.

D—*Cement* shall in all cases be approved by the Engineer of Bridges, and the Inspector in charge of the work shall receive a written approval before permitting concrete to be made from any cement delivered. Where possible, cement shall be delivered in time to have samples properly taken and sent to the office of the Engineer of Bridges, for making the usual one-day and seven-day tests of neat cement. Contractors shall provide storehouses at the site of the several pieces of work in which to unload and store cement. Cement which is delivered on board cars must be unloaded promptly and stored in such warehouses, and the cars returned to the company's service. In no case will it be permitted to retain box cars on the work for the storage of cement. Cars which may be so held shall be charged to the contractors at the rate of one dollar ($1.00) per day for each day after the second day so held unloaded. Contractors shall be responsible for the proper care of this cement after it has been received and stored, and any cement injured through carelessness or neglect shall be rejected promptly by the Inspector in charge. No brand of cement shall be used in any concrete work which has not been accepted in writing by the Engineer of Bridges, such acceptance to be based upon regular tests, where possible. The Inspector shall, from time to time, make small pats of pure cement, and of cement mixed with sand, to satisfy himself that the cement actually used is of uniform character, and has not been injured by exposure to weather or in any other way, and may reject any cement which is wet or lumpy, or which fails to set properly in sample pats, and the contractor shall remove the same promptly from the work.

4. *Natural Cement Concrete* may be used where foundations are entirely submerged below low water mark or where

there is no risk of the same being exposed to the action of the weather by cutting away the surrounding earth. Natural cement concrete, however, shall be used only where a firm and uniform foundation is found to exist after excavations are completed. In all cases where foundations are liable to be exposed to the action of the water, or where the material in the bottom of excavations is soft or of unequal firmness, Portland cement concrete must be employed for foundation work.

(See specification for using railroad iron in foundation.) (Par. No. 16.)

5. *Natural Cement Concrete* shall usually be made in the proportions (by measure) of one part of approved cement to two parts of sand and five parts of crushed stone, all of character as above specified. For Portland cement concrete foundations one part of approved cement, three parts of sand and six parts of crushed stone may be used. Wherever in the judgment of the Engineer or Inspector in charge of the work, a stronger concrete is required than is above specified, the proportions of sand and crushed stone employed may be reduced, a natural cement concrete of one, two and four, and a Portland cement concrete of one, two and five being substituted for those above specified.

6. *Portland Cement Concrete* for the bodies of piers and abutments, for all wing-walls for same, and for the bench walls of arch culverts shall generally be made in the proportions (by measure) of one part of cement, two and one-half parts of sand and six parts of crushed stone. Where special strength may be required for any of this work, concrete in the proportions of one, two and five may be used; but all such cases shall be submitted to the judgment of the Engineer of Bridges, before any change from the usual specification is to be allowed.

7. For *Arch Rings* of arch culverts and for parapet head walls and copings to same, Portland cement concrete, in proportions of one, two and five, shall generally be used. Concrete of these proportions shall also generally be used for parapet walls behind bridge seats of piers or abutments, and for the finished copings (if used) on wing walls of concrete abutments, also for arch work in combination with I-beams or in combination with iron work for transverse loading.

8. *Bridge Seats* of piers and abutments and copings of concrete masonry which are to carry pedestals for girders or longer spans of iron work, shall generally be made of crushed granite and Portland cement, in the proportion (by measure) of one part of approved cement, two parts of fine granite screenings, and three parts of coarser granite screenings, the larger

of which shall not exceed three-fourths inch in greatest dimension.

8a. *Jacketing Work* shall consist of concrete in proportions of one (1) part of cement, two (2) parts of sand and either four (4) or five (5) parts of fine crushed stone (selected, if necessary, so that the largest pieces shall not be over one and one-half (1½) inches in greatest dimension). This material shall be used as a coating over masonry which is in bad condition, the thickness to be used varying from a minimum of four (4) inches to a maximum of, say, ten (10) inches, and generally averaging at least six (6) inches in thickness. It shall also be used for linings of tunnels or culverts in which the masonry is defective, or where added strength is required. This material shall be placed in molds which shall generally be built slightly in advance of the work. Special pains shall be taken in placing and ramming this material, so as to produce a smooth exterior finish, and to fill completely all crevices either small or large in the old masonry. No facing mortar will be required in this work, but a finished face shall be produced by spading and working the fine material of the concrete next to the mold. Material of this character shall be paid for by the cubic yard at a special price to be named in the proposal.

MIXING CONCRETE.

9. All concrete must be mixed on substantial platforms of plank or boards securely fastened together, so that the various materials of the concrete can be kept entirely free from admixture of foreign matter. Hand-mixed concrete shall not be made in batches of more than one yard in each batch. The proper amount of the several kinds of material shall be measured in some way which is entirely satisfactory to the Engineer or inspector in charge of the work, so that they may be satisfied that the requisite proportions of each kind of material are delivered for each batch of concrete. Satisfactory methods of measurement will be the use of headless and bottomless barrels for measuring sand and broken stone; the use of boxes into which the sand and stone may be cast and leveled off (the boxes then being removed), or the use of square and uniform sized wheelbarrows, expressly designed for this purpose. The measurement of sand and broken stone in the ordinary shallow, round bottom wheelbarrow will not be considered satisfactory, and shall not be permitted.

10. The detail of mixing concrete by hand shall be generally as follows: the proper amount of sand shall be measured out and spread upon the concrete platform, and the proper amount of cement shall be delivered and spread upon the same;

the sand and cement shall be turned over dry, either by means of shovels or hoes, until they are evenly mixed. They shall then be wet and made into a rather thin mortar, and shall then again be spread into a uniform and thin layer upon the concrete platform. The proper amount of concrete stone (the same having been previously drenched with water) shall be spread upon the mortar, and the whole shall be turned over at least twice, either by shovels or hoes, before it is loaded into wheel-barrows, or in any other way taken to be placed in the work. In wetting the mixture of sand and cement to make the mortar, and in wetting the subsequent mixture of stone, sand and cement (if necessary), a spray or sprinkler shall be used. The water must not be dashed upon the mass in buckets or large quantities, or by means of a jet. The inspector shall insist that the resultant mixture of sand, cement and stone is as nearly as possible uniform in character, the mortar being equally distributed throughout the mass of the stone. The inspector shall also see that the mixture is neither too wet nor too dry. It should be of such a consistency that, when thoroughly rammed, it will quake slightly, but it should not be thin enough to quake in the barrow, or before ramming. The inspector shall satisfy himself that the proper proportions of cement, sand and stone are used, checking from day to day or from time to time with the total amount of each which is received and used.

11. Machine-mixed concrete shall be made of the same general consistency as the hand-mixed concrete above specified. Proper precautions shall be taken to see that the requisite proportions of the different ingredients are used. If machines are used which are not provided with devices to deliver each of them, the process of making the concrete shall generally be as follows: The proper amount of sand, cement and stone for a batch not to exceed one yard of concrete shall be delivered on the platform, and roughly mixed together so that when the dry mass is cut down and delivered to the mixer by means of shovels, proper amounts of each of the ingredients are handled in each shovelful.

It will not be regarded as a satisfactory process to deliver crushed stone, sand and cement at random to the mixer, without taking some special means, as above described, to insure the delivery of the proper quantities of each ingredient as nearly as may be simultaneously.

### MOLDS.

12. MOLDS of substantial character shall be made in which to construct all concrete work. The material for these molds shall be furnished by the contractor, and the expense of furnish-

ing this material and of constructing and removing all molds shall be covered in the price per yard paid to the contractor for the several classes of concrete work called for. The face of the mold next to the concrete shall be finished smooth, planks which are dressed at least on one side being employed for this purpose. Material for the molds shall be of sufficient thickness, and the frame holding them shall be of sufficient strength, so that they shall be practically unyielding during the process of filling, tamping, etc. The different parts of the frame work for the mold may be fastened together, if desired, by tie rods or wires extending through the concrete. If tie rods are used they shall be so designed that no iron work will be left outside of the concrete or within less than two inches from the face of the same when the molds are removed. This may be accomplished by sleeve nut connections which will permit the removal of the projecting ends of bolts or rods, etc., leaving only small holes in the concrete which can be stopped with pointing mortar after removing the molds. Another satisfactory method of bracing molds is to construct them with cross ties between the front and back, these ties to be placed at frequent intervals above the lower portion of the mold and to be removed as the concrete is built up, the studding out of which the molds are constructed being sufficiently long to extend above the top of the finished masonry, and at least one set of ties being used above this level. In general 2-inch plank, sized to approximately $1\frac{3}{4}$ inch thickness, shall be used for the facing of all molds, and studding for frames shall be placed at intervals not more than 4 ft. apart. The planking forming the lining of the molds shall invariably be fastened to the studding in perfectly horizontal lines, the ends of these planks shall be neatly butted against each other, and the inner surface of the mold shall be as nearly as possible perfectly smooth, without crevices or offsets between the sides or ends of adjacent planks. Where planks are used a second time, they shall be thoroughly cleaned, and, if necessary, the sides and ends shall be freshly jointed so as to make a perfectly smooth finish to the concrete.

13. The molds for projecting copings, bridge seats, parapet walls, and all finished work shall be constructed in a first-class, workmanlike manner, and shall be thoroughly braced and tied together, dressed surfaces only being exposed to the contact of concrete, and these surfaces shall be soaped or oiled if necessary, so as to make a smoothly finished piece of work. The top surfaces of all bridge seats, parapets, etc., shall be made perfectly level, unless otherwise provided in the plans, and shall be finished with long, straight edges, and all beveled surfaces or washes shall be constructed in a true and uniform manner.

Special care shall be taken in the construction of the vertical angles of the masonry, and where I-beams or other iron work are not used in the same, small wooden strips shall be set in the corners of the mold, so as to cut off the corners at an angle of forty-five (45) degrees, leaving a beveled face about one and one-half ($1\frac{1}{2}$) to two (2) inches wide, instead of a right angled corner.

14. Where wing walls are called for which have slopes corresponding to the angle of repose of earth embankments, these slopes shall be finished in straight lines and surfaces, the mold for such wing walls and slopes being constructed with its top at the proper slope, so that the concrete work on the slope may be finished in short sections, say from three to four feet in length, and bonded into the concrete of the horizontal sections before the same shall be set, each short section of sloped surface being grooved with a cross line separating it from adjacent sections. It will not be permitted to finish the top surface of such sloped wing walls by plastering fresh concrete upon the top of concrete which has already set, but the finished work must be made each day as the horizontal layers are carried up, to accomplish which the mold must be constructed complete at the outset; or, if the wing wall is very high, short sections of the mold, including the form for the slopes, must be completed as the horizontal planking is put in place.

15. Foundation concrete may be put into excavations without the use of molds, provided the sides of the excavation are reasonably true and the material is sufficiently firm, so that the concrete may be rammed thoroughly without yielding of the adjacent earth. Where a cheaper kind of concrete is used for foundation work, the top of the same shall be finished smooth and level, the corners and edges being thoroughly rammed and compacted, and the whole surface filled full of mortar. It will not be satisfactory to leave a honey-combed surface or one on which a lot of loose concrete stone is left scattered about.

It is not expected that the surface of such foundation work shall be accurately leveled unless cut stone masonry is to be built upon it, but the Inspector must insist that that portion of such foundation concrete which projects outside of the masonry which is to be built upon the foundation must be thoroughly rammed and compacted, and must have a finished surface. If this cannot be accomplished without constructing a mold for the upper portion of such foundation, the contractor shall furnish material and construct such mold, and the cost of the same shall be included in the price of the foundation concrete.

16. *Iron Rails* to be furnished by the Railroad Company shall be laid and imbedded in such manner as may be specified

in such foundation concrete as in the opinion of the engineer of bridges needs such strengthening, and no extra charge, except the actual cost of handling the same, shall be made by the contractor for such work, but the volume of such iron shall be estimated as concrete.

17. Where I-beams are to be placed in the angles of concrete piers as a protection against ice, drift, etc., these shall be set up and securely held in position so that they will extend one foot or more into the foundation concrete. The planking of molds shall be fitted carefully to the projecting angles of these I-beams and small fillets of wood shall be fitted in between the inner faces of the mold and the rounded edges of the I-beam flanges so that no sharp projecting angle of concrete will be formed as the work is constructed.

These fillets may be made in short pieces and fastened neatly into the mold as the layers of concrete are carried up. Such I-beams will generally be furnished of sufficient length to extend at least six inches above the top of the battered masonry into the concrete copings, and special pains shall be taken to tamp the concrete thoroughly around the I-beams, and to finish the coping above and around the ends of the same, so as to make a compact and solid bearing against the iron work.

18. Where anchor bolts for bridge seat-castings are required, they shall be set in place and held firmly as to position and elevation, by templets, securely fastened to the mold and framing. Such I-beams and anchor bolts shall be embedded in the concrete work without additional expense beyond the price to be paid per yard for the several classes of concrete in which such iron is placed, the volume of iron being estimated as concrete.

19. After the work is finished and thoroughly set, all molds shall be removed by the contractor. They shall generally be allowed to stand not less than forty-eight hours after the last concrete work shall have been done. In cold weather, molds shall be allowed to stand a longer period before being removed, depending upon the degree of cold. No molds shall be removed in freezing weather, nor until after the concrete shall have had at least forty-eight hours, with the thermometer at or above 40 degrees F., in which to set.

### PLACING CONCRETE.

20. Concrete shall generally be placed in the work in layers not exceeding six inches in thickness, and, in general, one layer shall be entirely completed before another one is commenced. If delivered by wheel-barrows it shall be dumped as closely as possible where required, so as to avoid as much as

possible the handling or turning over the same by means of shovels within the excavation or mold. Where it is not practicable entirely to complete one layer before commencing a second one, a plank, six inches wide or more, shall be securely fastened into the excavation or mold, against which the end of the layer of concrete shall be rammed, thus providing for a vertical joint in this layer of concrete, and if a second layer has to be stopped short of the full length of the work, a second cross plank, placed at least one foot back from the end of the first layer, shall be secured to the excavation or to the mold, against which to ram the second layer of concrete. Layers of concrete masonry must not be tapered off in wedge-shaped slopes, but must be built with square ends in the method above described, and the surface of each projection shall be finished hard and smooth, and flushed full of mortar, no porosities or loose stone being left thereon. Layers must not be made of greater thickness than six inches, unless specially permitted, and each layer must be thoroughly rammed, and the concrete must be of such consistency that heavy ramming will produce a slight quaking action. In other words, the concrete must be so thoroughly compacted that there will be no pores or open spaces between the stone of which it consists, which are not thoroughly filled with mortar.

The inspector shall insist upon the thorough compacting and ramming of all concrete, and shall see that a sufficient number of men, furnished with suitable rammers, are assigned to this work. Enough men shall be employed ramming, so that each batch may be spread and rammed before another batch is dumped within the mold. The ramming must be completed as the work progresses.

21. Foundation concrete, if put into excavations which are not protected by molds, need not have any special attention given to the finish of the concrete against the earth around it. Where it is necessary to use molds in the construction of foundation work, the finer material of the concrete shall be worked to the outer portion of the mass against the molds, so as to insure the filling with mortar of all pores or open spaces between the concrete stone. As before described, the top surface of all foundation concrete shall be finished, so that no loose stone or open and porous places are left upon the same, especially in the portions of the foundation which project outside the upper portion of the work. If necessary, the Inspector shall have the contractor make batches of mortar, consisting of one part of cement to three parts of sand, the same being thoroughly mixed, and shall cover the whole surface of the foundation concrete with enough of this mortar to flush full all such open, porous places.

22. *A Facing of Mortar,* consisting of one part of cement (by measure) to two parts of sand, shall be put in next to the molds, for all Portland cement concrete work for piers, abutments, arches, wing walls, parapet walls, and any other places where directed by the engineer in charge, to form a finish for all such parts of the above classes of work as are to be exposed to the weather, or which are liable to become so exposed. A similar facing shall be used for the top surface of all concrete masonry not finished with granitoid work, and such surfaces shall be finished in the style of sidewalk work.

It is not intended to use such a facing on the backs of abutments or wing walls, against which earth filling is to be placed, and where the same must necessarily be maintained, but the same shall be used for the faces and for the upper twelve inches on the backs of all wing walls, for the backs of parapet walls, for the intrados of all arch work, and as a plastering on the outside of the same, and in all such places where the washing away of earth may expose concrete work to the action of the weather. It is not intended to use such facing for any copings, bridge-seats, parapets, etc., which are to be of granitoid construction. The exact thickness of one and one-half inch for this facing shall be secured in the following manner: A piece of sheet iron six inches in width (the height of one course of concrete), and of any convenient length, say from six feet upwards, having small angle irons, the projecting leg of which shall be one and one-half inches in width riveted to its face, at intervals of about two feet, and provided with handles standing above the upper edge at or near each end, shall be furnished by the contractor for use at each piece of work where necessary. This piece of iron plate, if placed with the projecting angles against the face of the mold, will leave a space of one and one-half inches between it and the mold. This space shall be filled with the mortar required for the facing, which mortar shall be mixed in small batches from time to time as needed for the work. When the space between the iron plate and the mold is filled and tamped with a shovel or other tool to insure complete filling of the whole space between the iron plate and the face of the mold, and when the layer of ordinary concrete is backed up against this iron plate, it is to be withdrawn by means of the handles and the whole mass of concrete rammed in one uniform layer. The Inspector shall see that the space of one and one half inches is entirely filled with the mortar, which should be of a consistency so that it will flow somewhat freely. At the same time this mortar must not be made so thin that the crushed stone may be forced through it in the process of ramming. By using the mold in the manner above described, the face of each

layer may be made of exactly the right amount of mortar, and the proper thickness of the layer may be accurately determined. The intention is that the facing and the backing shall be rammed and set together. In no case is one to be put in advance of the other, or so that either may set before the other. In no case shall the Inspector or Engineer in charge permit any work to be finished by plastering mortar on concrete which has set, but should it become necessary at any time to refinish a surface which has set, it shall be picked off so that at least three (3) inches of mortar can be added, and the surface of the old concrete shall be roughened and thoroughly wet before new material is added, such new material being mortar as specified for facing.

23. Layers of concrete shall be kept truly horizontal, and if, for any reason, it is necessary to stop work for an indefinite period, it shall be the duty of the Inspector and of the contractor to see that the top surface of the concrete, is properly finished, so that nothing but a horizontal line shall show on the face of the concrete, as the joint between portions of the work constructed before and after such period of delay. If, for any reason, it is impossible to complete an entire layer, the end of the layer shall be made square and true by the use of a temporary plank partition, as specified in paragraph twenty (20). No irregular, wavy or sloping lines shall be permitted to show on the face of the concrete work as the result of constructing different portions of the work at different periods, and none but horizontal or vertical lines shall be permitted in such cases.

24. Where concrete is to be put into a foundation below water level, all water shall as far as possible be removed from the excavation. If it is impossible by means of the ordinary pumping facilities to control the flow of water, the excavation may be taken out in sections, and the concrete may be placed in the foundation, section by section. Special care should be taken to ram thoroughly the bottom layer of concrete, and to remove all mud and clay from the vertical face of each section of concrete, as additional sections are excavated and prepared for addition of concrete work. Where the foundation is soft, as, for example, where piles are used, either fine or coarse broken stone may be spread over the bottom of the excavation and thoroughly rammed into the earth before putting in any concrete. In no case shall a dry mixture of sand, cement and crushed stone be put into a foundation. The concrete may be mixed with a less proportion of water, but should not be placed in the foundation without thorough mixing. Where strata of gravel and sand permit the entrance of water into the foundation with such freedom that small sections of the same cannot be

excavated and pumped out for concreting, a grout of pure cement or of a mixture of cement and one or two parts of sand may be injected through a pipe into the loose gravel and sand in the bottom of the foundation; this work being done while the excavation is filled with water. The pipe through which this grout is passed should be pushed a few inches below the surface of the gravel, and a bucketful or more of grout should be poured down through the pipe, the pipe being then moved one or two feet, and the operation repeated, distributing the grout over the whole area of the bottom to be thus cemented, and the work then should be allowed to stand for twenty-four to thirty six hours. It will generally be found that the sand and gravel will be converted into a water-tight concrete, permitting the pumping out of the excavation.

25. Where it is impossible to complete parapet walls, copings, etc., on account of stringers or other wood or iron work necessary to maintain structures over which tracks are in use, all work shall be finished to horizontal and vertical lines, and with surfaces filled with mortar, so that when possible to complete the concrete work, the joint between the new and the old work shall show nothing but straight, level and vertical lines.

26. *Expansion Joints.*—Where masonry structures are more than one hundred feet in length, such provision for expansion joints shall be made as may be specified by the Engineer of Bridges or his assistants. Generally in the construction of large arches, or of smaller, long concrete arches, the work shall be subdivided into sections of approximately twenty-five feet in length, each section being separated from the adjacent one by a vertical joint extending entirely through the bench walls, arch rings, etc.; but the foundation work shall be stepped as previously explained, and made in one continuous monolithic mass. Temporary vertical partitions shall be put into the molds, against which the concrete shall be thoroughly rammed, where arch culverts are subdivided into short lengths, as above specified, these partitions being removed as each section is completed, and the next adjacent section being rammed against the concrete already constructed and set. The joints thus made shall not be flushed with mortar, nor shall any attempt be made to make the fresh concrete adhere to the older work, but a small beveled strip of wood shall be set in the angle next to the temporary partition so as to make a "V" groove, defining the joint and leaving a depth of, say, three-fourths ($\frac{3}{4}$) of an inch on the finished face of the work, it being the intention that any contraction shall open or that settlement shall effect a sliding action at such vertical joints, rather than to break up the concrete in the separate sections.

### POINTING.

27. After the molds are removed, if there should be found any small pits or openings on the exposed faces of the concrete (or if bolts are used for securing the molds the ends of which are removed, leaving small holes), all such holes, pits or porous places shall be neatly stopped with pointing mortar, made of equal parts of cement and sand and mixed in small quantities to be used before the same shall set. Although it has not been specified to use a facing of mortar for such masonry as is to be permanently buried or covered by earthwork, such masonry shall not be constructed and left with pores and honey-combed surfaces. All such pores and openings shall be stopped with a pointing mortar, composed of one part of cement and two parts of sand, the same to be neatly filled into all openings and smoothly finished, in advance of any filling against such work.

### NAME PLATE AND DATE.

28. A name plate and date shall be furnished by the contractor and put upon one piece of masonry at each bridge or job constructed by him, such plate to be of brass or copper or other durable metal, furnished with bolts or projections on the back to be buried in the concrete and to secure it firmly to the same, and having on it the contractor's name and the date of the year in which the concrete work is constructed. These plates should be placed upon the parapet walls of abutments, concrete arches and pipe culverts, and upon the ends of the bridge seats of piers, where they can be plainly seen and easily read. These should be set as the concrete work is finished and should be level with the surface of the same.

### EXTRA WORK.

29. It is the intention of the foregoing specifications that work of all kinds shall be done by unit prices. It shall be paid for at rates per unit of measure of the several kinds of work required. Wherever, in the judgment of the Engineer in charge, such prices are unfair to the contractor, the conditions shall be fully explained to the Engineer of Bridges, whose permission shall be obtained in writing for all extra work to be done. Generally such work shall be done at the actual cost, and the contractor shall be allowed ten (10) per cent. in addition, to cover superintendence, the use of tools, etc. No other rate will be allowed, unless specially provided when the work is ordered.

30. A daily report of forces employed and material used in all extra work shall be made by the Foreman on the work to the Assistant Engineer or Inspector in charge of the work,

who shall check the same from day to day and settle all disputed questions as to labor and material used. A return of all such extra work shall be made by the contractor (or by his foreman) at the end of each month, which shall be given to the Engineer or Inspector on the work for certification, and shall be sent to the Engineer of Bridges, with the estimate of work done at contract prices, so that the monthly estimate may cover all work done during the month. In general, all bills for extra work claimed to have been done by the contractors shall be rendered monthly and shall be certified to by the Engineer or Inspector in charge of the work.

### CLASSIFICATION OF PROPOSALS.

31. Contractors will be requested to name prices for the following materials and kinds of work:

*a.* A price per lineal foot for piles furnished and driven in cofferdams and foundations.

*b.* A price per M. ft. B. M. for timber, plank, boards, etc., used in cofferdams, sheeting, etc.

*c.* A price per cubic yard for dry excavation.

*d.* A price per cubic yard for wet excavation.

*e.* A price per cubic yard for rock excavation.

*f.* A price per cubic yard for foundation concrete of natural cement, proportions of one, two and five.

*g.* A price per cubic yard for foundation concrete of natural cement, proportions of one, two and four.

*h.* A price per cubic yard for foundation concrete of Portland cement, proportions of one, three and six.

*i.* A price per cubic yard for foundation concrete of Portland cement, proportions of one, two and five.

*j.* A price per cubic yard for Portland cement concrete in piers, abutments, bench walls of arch culverts and wing walls, including mortar facing, proportions of one, two and one-half and six.

*k.* A price per cubic yard for Portland cement concrete in arch rings of arch culverts, parapet walls, copings, etc., proportions of one, two and five (including mortar facing for same).

*l.* A price per cubic yard for granitoid concrete as specified for bridge seats and copings, proportions of one, two and three.

32. The prices for all kinds of concrete (except foundation concrete) are to include all molds, framing, tie rods, braces, etc., required in constructing concrete, in accordance with the detailed plans.

MARCH, 1900.

ACCEPTED ......... ...... ...... ...... ......Contractor.

**174. Specifications for Railway Road-bed.** The following specifications cover all the work of building a road-bed of a railroad including clearing, grading, and all fixed structures which make a part of the road-way with the exception of span bridges. It is the latest form (1902) used by one of the leading and most careful railroad consulting engineers in the country and a past President of the American Society of Civil Engineers. The general stipulations are not included here.

CLEARING AND GRUBBING.

The whole width of the right-of-way shall be cleared of all trees, stumps, logs, brush and other perishable matter, and all fences and buildings which come within the limits of the right-of-way shall be removed to or beyond these limits.

Under embankments less than three feet in height, and wherever there is an excavation of any depth, all trees, stumps and brush shall be grubbed out, and under embankments three feet or more in height they must be cut off close to the ground.

All timber on the right-of-way is the property of the Railway Company or of the owners of the land, and in the latter case may be removed by them within a reasonable time. All timber not so removed shall be cut by the Contractor into such lengths and piled in such manner as may be directed by the Engineer. All stumps, brush and worthless timber are to be burnt up when it can be done with safety; but in no case are tree tops or other rubbish to be thrown onto adjoining land, except with the consent of the land owner.

Clearing shall be paid for by the lump sum or by the acre, the price paid therefor being understood to include all necessary grubbing.

The removal of fences excepting hedges shall be done without charge, and that of buildings at such price as may be agreed upon or may be fixed by the Engineer in the absence of an agreement.

Hedge fences must be grubbed out within the limits of the right-of-way and completely burned up, for which a price of......per hundred feet will be paid.

GRADING.

*General Requirements.*—Under the head of grading will be included all excavations and embankments needed for the formation of the road bed and for all accessory works, such as foundation pits, new channels for streams, road crossings and new roads which may be directed by the Engineer.

As a rule the following side slopes and widths at grade will be used: In earth excavations 22 feet at grade, with side slopes of one horizontal to one vertical. In rock excavations 18 feet at grade, with side slopes of one-fourth horizontal to one vertical.

In embankments the side slopes shall be one and one-half horizontal to one vertical, and the width at grade shall be for banks less than six feet in height, sixteen feet; for banks six feet in height and up to sixteen feet in height, eighteen feet; and in banks over sixteen feet in height, twenty feet; but these widths and slopes may be varied at the discretion of the Engineer.

The road bed and the slopes of all excavations and embankments must be neatly and truly finished to the stakes and directions given, and no wheel tracks or other depressions left which will lead the water along the road. After finishing the work the contractor must build such fences or other obstructions as will prevent teams from driving along the road and maintain them until the final acceptance of his work, and he must repair any damage resulting from neglect of this precaution.

In rock cuts the Contractor will, as a rule, be required to carry excavations six inches below the ordinary sub-grade, in order to allow for ballasting. If of suitable quality, the rock thus excavated shall be broken up so that it will all pass through a two-inch ring and be left in good surface to receive the track. For this breaking and surfacing an additional allowance of 25 cents per yard measured in excavation will be allowed.

*Excavation and Ditching.*—All material taken from excavations, whether for the road bed or for ditches, new channels, or other accessory works, shall be used as the Engineer shall in each case direct. Where there is any surplus beyond what is needed for the embankments, which for this purpose may be widened to any extent, it shall be deposited in spoil banks. All spoil banks shall be sloped on the side next the road with a slope not steeper than one and one-half to one, and be kept at least six feet from the edge of the excavation.

The Contractor when so directed by the Engineer, shall deposit at such convenient points as he may designate, any stone or other valuable material which may be found in the excavations. All material so deposited shall be the property of the Railway Company, and the Contractor will be held responsible for its safe keeping until removed by said Company, or until this contract is closed.

All falls or slides from the sides of the excavations shall

be taken out by the Contractor, and, except when due to his carelessness or neglect, will be paid for at the same price as other excavation.

Side ditches along the road bed in excavations shall be cut of such widths and depths as the Engineer may direct. Drainage ditches outside of the excavations as well as new channels for streams shall be made whenever directed by the Engineer.

Excavation for foundation pits under water or for deepening new channels in running water will be paid for at such price as may be agreed upon, or as may be fixed by the Engineer in the absence of an agreement. But in either case the price paid shall cover the cost of all pumping, bailing and all labor and materials used in such excavation.

*Embankments.*—As a rule earth embankments, except as herein otherwise specified for filling over culverts, must be built with wagons or scrapers. The Engineer, however, may permit the use of cars where such use will materially expedite the work or reduce its cost.

All embankments must be commenced and carried up to the top at full width, the sides being kept at all times as high as the center, and be built up in layers not exceeding four feet in thickness, in such manner as to make the bank as compact as possible. They shall also be carried to such height above the final grade line as the Engineer may deem necessary to provide for shrinkage, washing and settlement, and be maintained at their proper height and width until accepted by the Chief Engineer, but the computation of quantities shall be made from the true cross sections to which it is presumed the embankments will finally settle.

In filling over masonry culverts care must be taken to avoid injury or distortion to the masonry, and if directed by the Engineer, the earth shall be wheeled or placed with shovels over and around the culverts and be carefully rammed in thin layers. For such wheeling and tamping such allowance will be made as the Engineer shall deem just.

No logs, stumps, brush or other perishable materials will be allowed in any embankments.

*Borrowing.*—In case sufficient material cannot be obtained by hauling from the excavations, the deficiency may be made up by borrowing, subject, however, to the direction of the Engineer, in each case as to the place from which to borrow.

Borrow pits alongside the railroad shall not be brought nearer to the toe of the embankment than six feet, nor nearer to the right-of-way line than two feet, and shall have a slope next the railroad not steeper than one and one-half to one. Borrow pits must be excavated neatly, irregular edges and deep-

holes being avoided, and they must be so connected together as to give efficient drainage along the railroad.

*Classification of Materials.*—The materials found in excavations will be classed as Solid Rock, Loose Rock and Earth, the Chief Engineer being in every case the final judge as to the class to which any material belongs.

Solid Rock will include all loose boulders containing one cubic yard or more, and all hard rock in compact strata or ledges exceeding six inches in thickness, which, in the judgment of the Engineer, cannot be loosened except by blasting.

Loose Rock will include all loose boulders containing more than two cubic feet, and less than one cubic yard, and all materials requiring the use of pick and bar, or which cannot be plowed with a strong ten-inch grading plow, well handled, drawn by a good six-horse team.

Earth will include all materials of whatever kind which do not clearly belong to one or the other of the foregoing classes.

Whenever material of any kind other than Earth is found in an excavation, the Contractor shall at once notify the Engineer in charge, so that he may make the necessary measurements to determine its quantity. If the Contractor shall fail to give such notice, the Engineer may presume that the measurements taken at the time he first sees the material in question will give the true quantity.

Solid or Loose Rock excavation will be paid for by adding to the price of Earth excavation an extra price named in the contract, which shall cover the additional cost of loosening and loading the material.

### RULES FOR MEASUREMENTS.

For payment, earth work will be divided into three classes, as follows:

All material taken from excavations of every kind, excepting borrow pits, will be classed and paid for as excavation.

Earth taken from borrow pits opened to furnish material not obtainable from other sources and delivered in embankment, will be classed and paid for as earth borrowed. So much of the material from excavations or borrow pits as is necessarily hauled more than three hundred feet, will be classed as material overhauled, and a price in addition to that for earth excavated or earth borrowed will be paid for the hauling, said price to be a price per cubic yard for each one hundred feet of haul in excess of three hundred feet.

Earth excavated will be measured in excavation; earth borrowed, where the whole embankment is made of earth, will

be measured in embankment. Where the bank is made partly of rock and partly of earth, the amount of earth borrowed may be determined either by measuring the borrow pit or by measuring the embankment, as in the judgment of the Engineer, will give the greater certainty.

Solid rock and loose rock will be measured in excavation, and in computing overhaul, the number of yards hauled will be determined by the measurement in excavation and the disance hauled determined by the volume of the embankment actually made from it.

## MASONRY.

*General Conditions.*—All masonry must be built in accordance with the plans and dimensions furnished by the Engineer, and be subject also to the directions of any Superintendent or Inspector of Masonry appointed by him.

All masonry will be paid for by the cubic yard, measured in the finished work, and the amount so paid shall be in full for all labor and materials used in the work, including cost of scaffolding and centering, and the repairing of all damages to the unfinished work from floods or other causes.

*Materials.*—All stone used in masonry must be sound and durable stone, approved by the Engineer, and be used in blocks as large as the quarries will furnish, or as may be necessary to comply with these specifications or the plans of the particular structure.

For brick masonry only the best quality of strictly hard dark red bricks shall be used, all to be of uniform texture throughout and free from lime or other impurities. No soft bricks will be allowed in any part of the work, nor shall any clinkers or any broken bricks be brought upon the ground. Bricks broken afterwards in handling shall be used in such manner only as the Engineer or the Inspector may direct. If so required, the Contractor shall furnish men at his own expense to cull the bricks under the direction of the Inspector, and all rejected bricks must be at once removed from the line of the work.

Unless otherwise agreed, cement for use in all masonry will be furnished by the Railway Company to the Contractor, and be delivered at.........................................
For each barrel of cement so delivered the Contractor will be charged..................dollars to be deducted out of any moneys due under this contract. Cement, after it is received by the Contractor, must be kept under cover and dry until

used. If allowed to become wet or damaged from any cause, it will be rejected and must not be used in the work.

Mortar for use in the masonry, except when otherwise specified, shall be composed of one part cement to three parts clean, sharp silicious sand, from which all sticks and gravel have been removed by screening. The proportions of cement and sand shall be determined by measurement, and shall be thoroughly mixed dry, in a suitable box. Enough water shall then be added to give the mortar the proper consistency, care being taken to avoid an excess of water. All mortar shall be made fresh for the work in hand, and no mortar used which has begun to set.

Concrete will be made of clean, hard, angular broken stones, of not more than two inches in the greatest dimension, mixed with smaller stones not less than one-fourth of an inch in the greatest dimension, and with mortar in such quantity as to be from five to ten per cent in excess of the volume necessary to fill the void spaces of the stone, the amount of mortar required for this purpose to be in every case determined by the Engineer. When mixed by hand, concrete must be mixed on tight-jointed plank platforms. The mortar will first be made as directed in the preceding paragraph, and the stone having been washed clean will then be added while wet, and the whole mass turned over twice with shovels. Concrete may also be mixed by machine, provided that in the judgment of the Engineer the mixture is as complete and the result in all respects as good as if done by hand in the manner just described.

*Forms.*—The forms for shaping concrete work shall be made of pine planks twelve inches wide and not less than two inches thick, dressed to a smooth surface on one side and both edges. The dressed face shall be on the side next the concrete. The forms shall be framed and braced in accordance with plans furnished, or approved, by the Engineer.

*Depositing and Ramming Concrete.*—All concrete shall be deposited in layers not exceeding nine inches thick, and be rammed until the mortar flushes to the surface. If, when this is done, the mass quakes, the amount of water shall be reduced until this is avoided.

In placing concrete upon the foundation already built, the foundation shall be swept clean and then covered with a wet layer of mortar not less than one inch thick to make a close joint between the wall and the foundation.

In filling a form the work shall be carried on continuously so that it shall be a monolithic mass without horizontal joints. The part next the outer side or showing face of the wall shall

be filled with facing mortar, made of one part Portland cement and two parts sand. The thickness of the facing shall not exceed one and one-half inches, nor be less than three-fourths of an inch. The facing and backing must go on simultaneously in the same horizontal layers. In order to guage the thickness of the facing accurately, a light board or diaphragm of thin metal and with convenient handles shall be set on edge parallel to, and one and one-half inches from the front wall of the form. Facing material shall be deposited in the space between this board and the form. Concrete for the backing shall then be deposited and spread against the back of the board, which shall then be withdrawn and the whole mass thoroughly rammed so as to bond the facing and backing by destroying the surface of demarkation between them, but no stone must be forced nearer to the front wall of the form than three-fourths of an inch.

Concrete or mortar shall not be made when the temperature is lower than 35 degrees Fahrenheit in the shade, or when rain is falling on it. Forms and molds must be left in position for not less than four days after the concrete is deposited. Freshly deposited concrete shall be protected from the direct rays of the sun and from wind by boards or tarpaulins, and as soon as a section of wall is completed the top must be covered, with a layer of damp sand not less than two inches thick, which shall be kept moist until the concrete has set.

The walls of the wooden forms shall be kept well wet during the progress of the concrete work.

*Brick Masonry.*—In laying brick masonry every brick must be cleaned and thoroughly wet just before being laid. Every brick shall be laid with a "push joint," that is, by placing sufficient mortar on the wall and forcing the bricks into it in such a manner as to completely fill every joint with mortar, whether at the bottom, side or end of the brick. The joints shall be made as nearly as possible of uniform thickness, not exceeding half an inch. The face joints shall be left full and be neatly struck. All unfinished work must be racked back in courses, unless otherwise directed, and when new work is to be joined to it the surface of the unfinished work must be cleaned and wetted.

For the inside of arches and for the exposed face of all walls only the smoothest and hardest bricks, carefully selected for that purpose, shall be used, great care being taken to lay them to true cylindrical and plane surfaces.

In arches the bricks shall be stretchers so laid as to break joints with those in adjoining courses. All other walls shall

be laid in English bond, that is, with alternate courses of headers and stretchers, each course breaking joints with the course below. No broken bricks shall be used in the face of any wall, except when necessary to make closures or to break joints.

*Foundations.*—Unless otherwise specially agreed or directed, the foundations for all masonry shall be prepared by the Masonry Contractor, and in case a natural bed sufficiently firm is not found at a reasonable depth, he shall prepare such artificial foundation of timber, concrete or other material as the Engineer may direct.

Where a price is named in this contract for timber or other materials used in foundations, it is intended to cover every expense of furnishing the material and putting the same in place, the amounts paid for being those found in the finished structure. And where a price is named for excavation in foundation pits below water, it is intended to cover the cost of pumping, bailing and shoring, and every other expense incident to the removal of the material.

*Paving and Slope Walls.*—Paving, wherever required, will be laid of flat stones set on edge and well rammed, so as to make a good, smooth and close pavement one foot thick, confined at the ends and sides by deep curb stones. Each paving stone shall have a depth of not less than twelve inches.

Wherever required to protect an embankment from the action of water, a pavement or slope wall similar to the foregoing shall be laid on the slope of the embankment, said wall being begun at such depth below the surface of the ground as the Engineer may direct.

*Pipe Culverts.*—Pipe culverts shall be made of the best quality double strength vitrified clay pipe. Each pipe must be sound and straight, and shall not vary more than half an inch from a true circle. The thickness of twelve-inch pipes shall not be less than one and one-eighth inches; of fifteen-inch pipes not less than one and one-quarter inches; of eighteen-inch pipes not less than one and one-half inches; and of twenty-four-inch pipes not less than two inches.

In laying pipes the trench must be made true to line and grade, the bottom being shaped to exactly fit the lower half of the pipe, with cross trenches to receive the sockets so that each pipe may have a uniform bearing from end to end.

The pipes shall be joined by filing the space between the socket and spigot with a mortar of pure cement without sand. Particular attention must be given to the lower half of the joint where the cement should be pressed into it with the fingers or some tool specially fitted for the purpose. As each joint is

filled, all surplus cement must be carefully removed from the inside of the pipe.

After the pipes are properly laid they must be carefully covered with earth, well rammed, both on the sides and top of the pipe for at least twelve inches in depth.

At the ends of pipes culverts, such parapet or protection walls of brick, stone or concrete shall be built as the Engineer may direct, said walls to be laid in accordance with the foregoing specifications, and paid for by the cubic yard measured in the wall.

Pipe culverts will be paid for by the linear foot measured from end to end of the pipes when laid, the price so paid to cover the whole cost of materials and labor of every kind incident to the completion of the work.

### TIMBER TRESTLING.

*General Requirements.*—All timber structures, including pile and frame trestles, wooden abutments and piers, must be built according to the plans and instructions furnished by the Engineer. The drawings will be to scale, but in all cases dimensions are to be taken from the figures and not by scale. In case any dimensions are omitted, the matter shall be referred to the Engineer. Timber, iron and piles will be paid for in the finished structure, and the prices paid are to cover the cost of materials, tools, scaffolding, excavation, watching and all other items of expense necessary for the execution and maintenance of the work until its final acceptance. No waste of any kind will be paid for except "piles cut off," which will be paid for at the contract price.

The Contractor shall render the Inspector or Pile Recorder any assistance that may be required in the performance of his work.

*Piles.*—Piles shall be sound and straight sticks of white oak or red cypress, cut from living trees, and shall have all the bark peeled off. Each pile must have at least twelve inches of heart where cut off to receive the cap, and at the smaller end must be not less than nine inches in diameter.

All piles must be properly pointed, or if required, shod with iron shoes, and then driven until they sink not more than five inches under the last five blows of a 2,000 pound hammer, falling twenty-five feet, but a heavier hammer with a shorter fall, equivalent in effect to the foregoing, will be preferred. In driving, the piles must be capped with wrought iron rings, or preferably, with a cup-shaped iron follower, to prevent splitting. Where iron shoes are required, they must be of a kind directed

or approved by the Engineer, and they will be paid for at actual cost to the contractor. All piles injured in driving or driven out of place shall be either cut off or withdrawn, as the Engineer will direct, and another one driven in its stead. The pile thus replaced will not be paid for.

Such grubbing as may be necessary to insure the correct driving of the piles shall be done by the Contractor for the trestling, and will be paid for at a price to be fixed by the Engineer in each case.

The piles under the track stringers must be accurately spaced and driven vertically. The outer piles shall be driven vertically or with a batter, as may be shown by the drawings or directed in each case.

Piles remaining in the structure will be measured and paid for by the linear foot after they are driven and cut off as "Piles Driven," the parts cut off will be measured and paid for by the linear foot as "Piles Cut Off," and the amounts paid for these two items are to cover every expense for labor and materials required in the performance of the work. The pile ends, after they are cut off, are to be the property of the Railway Company, and shall not be removed or used without consent of the Engineer, and then only upon repayment of the contract price.

Parts of the pile heads projecting beyond the caps must be adzed off to a slope of forty-five degrees.

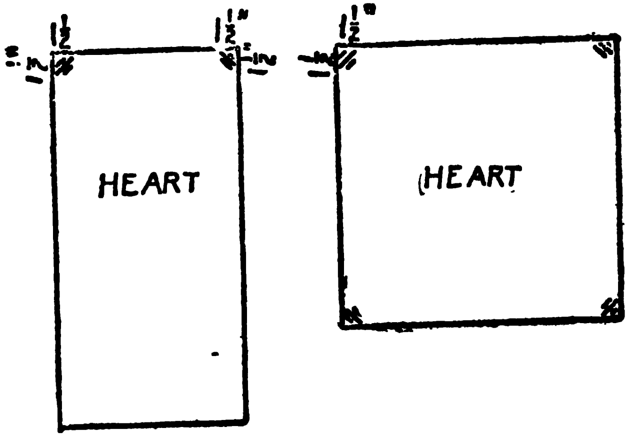
*Iron.*—The iron bolts used in trestling shall be of the best refined wrought iron, with an ultimate strength of not less than 45,000 pounds per square inch, and an elastic limit of not less than 26,000 pounds.

All bolts shall be perfect in every respect with nuts, heads and screws of the full standard sizes due to their diameters. The thickness of the nut shall not be less than the diameter of the bolt, and the size of its square not less than twice the diameter of the bolt.

Washers and separators shall be of cast iron. They must be smooth, well shaped, free from air holes, cracks, cinders or other imperfections.

*Timber and Framing.*—All framing timber shall be of white or burr oak, or of white Arkansas or long leaf yellow pine, as shown by the plans and bills of materials. All the timber must be cut from living trees and be free from wanes, black, loose or unsound knots, worm holes, or any kind of decay, as well as from large knots or wind shakes, which impair the strength of the timber, and must be sawed true and of full size. When so indicated on the plans, the timber shall be surfaced.

Sap will be allowed in pine timber as follows: All stringers must show not more than one and one-half inches of




sap on two corners of one of the eight-inch faces. Posts, caps, sills and other large timbers must show not more than one and one-half inches of sap on any one of the four corners. Guard rails must not show more than one inch of sap on one corner only. Sway braces and floor plank must show heart on both faces, and in any cross section be not less than three-fourths heart.

All framing must be done to a close fit and in a thorough and workmanlike manner. No shins or blocking of any kind will be allowed in making joints. Ties and guard rails must be scribed and dapped in place.

Tops and ends of stringers and the bearing surfaces of ties shall be thoroughly painted with a thick coat of pure white lead ground in and mixed with pure linseed oil. This paint shall also be used on both surfaces of the bearing between stringers and caps, caps and posts, posts and sills, sills and piles, or any other joints which may be indicated on the drawings.

*Cleaning Up.*—After the work is completed the Contractor must remove all staging used in erection, and clean up and burn all shavings, chips and rubbish, and remove all pieces of timber to a sufficient distance from the structure to insure its safety from fire.

*Word Engineer Defined.*—The word "Engineer," where-ever used in this instrument, means the Chief Engineer of the Southern Missouri Railway Company for the time being, or his duly authorized Assistants, or Inspectors, limited by the particular duties entrusted to them. R. M.

**175. Specifications for Building Levees to Confine Flood Waters.** The following specification is used (1902) by the State of Louisiana for the building of levees on the banks of the Mississippi river.

The levee shall be built of such material, and disposed and distributed in such manner as the Engineer in charge may direct, under the requirements of the Board of State Engineers. The required allowance for settling shall be added to the height of the levee; this allowance to be at the discretion of the Engineer in charge, up to one-fifth in excess of the net height of the levee; it being understood that a cubic yard of embankment under this agreement is a net cubic yard of settled earth, and equal to five-sixths of a gross cubic yard of loose earth.

The Contractor shall remove all trees, stumps, logs, roots, stalks, weeds, grass, trash and perishable matter of every kind not specially exempted from this requirement by instructions from the Engineer in charge, and plow or spade up the ground over the entire surface to be covered by the embankment. He shall cut muck ditches of such depth and size and in such places as may be prescribed by the Engineer in charge. He shall grub up by the roots all trees and stumps coming within the base of the levee, and three feet on either side of the base. He shall remove all buried logs, brick or walls and other material considered unsuitable by the Engineer in charge. He shall refill all holes made by grubbing or by the removal of unsuitable materials, as aforesaid, with solid earth up to the level of the natural surface; and the filling of such holes shall not be paid for by the cubic yard (except in special cases, when so directed by the Engineer in charge), but shall be a part of the clearing and grubbing to be done as incidental or auxiliary work, the price of which is included in the price per cubic yard hereinafter stipulated. He shall carefully clean all ditches crossing the line of levees, and fill them with solid earth up to the level of the natural surface to a distance of twenty feet from the base of the levee on the land side, where there are no "banquettes," and to the width of the berme on the river side. If required by the

Engineer in charge, the clearing, grubbing, preparation of base and cutting of muck ditch, as above, shall be completed, and the muck ditch refilled throughout the whole length of levee, or any part thereof, before the embankment is begun. He shall cut all trees and stumps within twenty-five feet of the base of the levee on the land side, down to the level of the ground, unless otherwise directed by the Engineer in charge (but shall not disturb or destroy the Engineer's bench marks or other reference points), and shall leave the ground clear of all fallen timber, brush and other debris or material obstructing free passage along the base of the levee on the land side for a width of twenty-five feet. He shall cut down all trees, bushes and saplings for a width of one hundred feet on each side of the levee where it runs through woods, and in open land, shall cut down such trees within one hundred feet of the levee as the Engineer in charge may direct. In the construction of the levee he shall use earth only, except where other material may be ordered by the Engineer in charge, and shall place it in layers of such thickness as may be directed by the Engineer in charge, and extending the full width of the embankment. He shall obtain all earth from the river side of the embankment, except by written permission of the Engineer in charge, leaving a berme of the natural surface ——— feet wide between the barrow pits and the base of the levee. Unless otherwise directed by the Engineer in charge, all barrow pits shall be sloped on the side nearest the embankment, not steeper than three horizontal to one vertical, and on that side shall not be deeper than three feet; and their bottoms shall slope thence uniformly to the side furthest from the embankment, where the depth of the pits shall not exceed six feet. At intervals not greater than three hundred feet "traverses" of the natural surface, not less than twenty feet wide, shall be left undisturbed, extending entirely across the pits, except that a ditch of such width as may be directed by the Engineer in charge shall be cut through the traverses to allow drainage from one part of the pit to another. All existing levees, or parts of old levee, must be left undisturbed except by special permission of the Engineer in charge. He shall cut such openings through the old levee as may be required by the Engineer in charge. He shall dig a drainage ditch on the land side of the levee, if required by the Engineer in charge, of such dimensions and at such distance from the base as may be prescribed, but may not otherwise break up the surface of the ground on the land side of the levee, except by written permission of the Engineer in charge. The earth taken from such openings through the old levee and from drainage ditches shall, when required by the Engineer in charge, be deposited in the

embankment, in which case it shall be paid for as embankment only, but otherwise it shall be measured and paid for in excavation. He shall plant the entire surface of the completed levee with living roots or sods of Bermuda grass not more than one foot apart, and to the satisfaction of the engineer in charge. He shall take care to preserve the engineer's stakes and bench marks, and shall at all times keep the station stakes at or opposite their proper stations.

**176. Complete Specifications and Contract for Dam No. 5, Southborough, of the Boston Waterworks, July, 1893.**

## ADVERTISEMENT.

TO CONTRACTORS.

Sealed proposals addressed to the Boston Water Board, and endorsed "Proposals for building dam No. 5 in the town of Southborough," will be received by the Boston water board, at their office, city hall, Boston, Mass., until 12 o'clock M., of Monday the seventeenth day of July, 1893, and at that time will be publicly opened and read.

Each bidder must make a personal examination of the location of the dam.

All bids must be made upon blank forms, to be obtained of the city engineer, Boston, must give the prices proposed, both in writing and in figures, and be signed by the bidder, with his address.

Each bid is to be accompanied by a certified check for two thousand dollars ($2,000), payable to the city of Boston, said check to be returned to the bidder unless he fail to execute the contract, should it be awarded to him.

A bond for one hundred thousand dollars ($100,000) will be required for the faithful performance of the contract, the sureties to be residents of Massachusetts, and satisfactory to said Boston water board.

The person or persons to whom the contract may be awarded will be required to appear at this office with the sureties offered by him or them, and execute the contract within six days (not including Sunday) from the date of notification of such award, and the preparation and readiness for signature of the contract; and in case of failure or neglect so to do, he or they will be considered as having abandoned it, and the check accompanying the proposal shall be forfeited to the city of Boston.

All bids will be compared on the basis of the engineer's estimate of quantities of work to be done, which is as follows:

(*a*) 14,000 cubic yards soil excavated and placed in spoil-banks.
(*aa*) 13,900 cubic yards soil excavated from spoil-banks and placed on dam.
(*b*) 1,610 square yards sodding.
(*bb*) 5 acres seeding.
(*c*) 230,000 cubic yards earth excavation (trenches, embankments, and backfilling).
(*cc*) 10,000 cubic yards rehandling of excavated materials.
(*d*) 13,400 cubic yards rock excavation.
(*e*) 2,000 feet board measure timber work.
(*ee*) 2,000 feet board measure timber work (tongued and grooved).
(*f*) 800 barrels Portland cement.
(*g*) 14,000 cubic yards concrete masonry.
(*gg*) 800 cubic yards concrete masonry.
(*h*) 9,270 square yards plastering.
(*i*) 256 cubic yards brick masonry.
(*j*) 7,500 cubic yards paving.[1]
(*k*) 10,100 cubic yards riprap.
(*l*) 5,400 cubic yards broken stone.[2]
(*m*) 22,200 cubic yards rubble-stone masonry.
(*n*) 13,300 square feet facing stone masonry (broken ashlar work).
(*o*) 3,650 cubic yards facing stone masonry (range work).
(*p*) 320 linear feet coping.
(*q*) 290 cubic yards dimension stone masonry.
(*r*) 4,110 square feet hammered work.
(*s*) 1,000 cubic yards masonry laid in American cement mortar 1 to 1, an additional price per cubic yard.
(*t*) 1,000 cubic yards masonry laid in Portland cement mortar 1 to 1, an additional price per cubic yard.
(*u*) 1,000 cubic yards masonry laid in Portland cement mortar 1 to 2, an additional price per cubic yard.
(*v*) 1,000 cubic yards masonry laid in Portland cement mortar 1 to 3, an additional price per cubic yard.
(*w*) 1,575 linear feet of walk.

These quantities are approximate only, and the Boston water board expressly reserves the right of increasing or diminishing the same as may be deemed necessary by its engineer.

Plans can be seen and specifications and forms of proposal and contract obtained at the office of the city engineer, city hall, Boston.

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[1] 3,200 cubic yards if riprap is used. [2] 2,800 cubic yards if riprap is used.

The Boston water board reserves the right to reject any or all bids, should it deem it to be for the interest of the city of Boston so to do.

ROBERT GRANT,
JOHN W. LEIGHTON,
THOMAS F. DOHERTY,
*Boston Water Board.*

OFFICE OF BOSTON WATER BOARD,
CITY HALL, BOSTON, JULY 1, 1893.

## PROPOSAL.

TO THE BOSTON WATER BOARD FOR BUILDING DAM NO. 5 IN THE TOWN OF SOUTHBOROUGH.

The undersigned hereby declares that he has carefully examined the annexed form of contract and specifications and the drawings therein referred to, and made an inspection of the site of the proposed dam, and will provide all necessary machinery, tools, appartus and other means of construction, and do all the work and furnish all the materials called for by said contract and specifications and the requirements under them of the engineer, for the following sums, to wit:

(*a*) For the removal of soil excavated and placed in spoil-banks, including all incidental work, the sum of —— ($——) per cubic yard.

(*aa*) For the removal of soil taken from spoil-banks or from other places and placing on the slopes of the embankment, including all incidental work, the sum of —— ($——) per cubic yard.

(*b*) For sodding, including all incidental work, the sum of —— ($——) per superficial square yard.

(*bb*) For seeding, including all incidental work, the sum of —— ($——) per acre.

(*c*) For earth excavation, including its disposal in embankments and refilling, or as otherwise ordered by the engineer, and all incidental work, the sum of —— ($——) per cubic yard.

(*cc*) For rehandling of excavated materials from spoil-banks and placing, including all incidental work, the sum of —— ($——) per cubic yard.

(*d*) For rock excavation, including its disposal and all incidental work, the sum of —— ($——) per cubic yard.

(*e*) For permanent timber work, except tongued and grooved timber, placed, including all incidental work, the sum of —— ($——) per thousand feet B. M.

(*ee*) For permanent timber work, tongued and grooved, placed, including all incidental work, the sum of —— ($——) per thousand feet B. M.

(*f*) For Portland cement ordered by the engineer, delivered where ordered on the work, in barrels containing 400 pounds, including all incidntal work, the sum of —— ($——) per barrel.

(*g*) For concrete masonry, in place, formed of five parts of broken stone or screened gravel, to one part of cement, and made with American cement mortar mixed in the proportion of one part of cement to two parts of sand, including all incidental work, the sum of —— ($——) per cubic yard.

(*gg*) For concrete masonry, in place, formed of three parts of broken stone or screened gravel to one part of cement, and made with American cement motar mixed in the proportion of one part of cement to two parts of sand, including all incidental work, the sum of —— ($——) per cubic yard.

(*h*) For plastering all concrete walls with Portland cement, including all incidental work, the sum of —— ($——) per superficial square yard.

(*i*) For brick masonry, laid in Portland cement mortar mixed in the proportion of one part of cement to two parts of sand, and including all pointing, centering, etc., and removing the same, and all incidental work, the sum of —— ($——) per cubic yard.

(*j*) For paving in place, including all incidental work, the sum of —— ($——) per cubic yard.

(*k*) For riprap in place, including all incidental work, the sum of —— ($——) per cubic yard.

(*l*) For broken stone in place (other than that used in making concrete and the walk), including all incidental work, the sum of —— ($——) per cubic yard.

(*m*) For rubble-stone masonry, laid in American cement mortar, mixed in the proportion of one part of cement to two parts of sand, including all incidental work, the sum of —— ($——) per cubic yard.

(*n*) For face work of broken ashlar, in addition to the price paid per cubic yard as rubble, including pointing in neat Portland cement, and all incidental work, the sum of —— ($——) per superficial square foot.

(*o*) For facing stone masonry of range stones laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand and pointing in neat Portland cement, including all incidental work, the sum of —— ($——) per cubic yard.

(*p*) For coping laid in place, and pointed in neat Portland

cement, including all incidental work, the sum of —— ($——) per linear or running foot.

(*q*) For dimension stone masonry laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, including pointing in neat Portland cement, centering, etc., and all incidental work, the sum of —— ($——) per cubic yard.

(*r*) For fine hammer dressing (six cut work) the sum of —— ($——) per superficial square foot.

(*s*) For all kinds of masonry laid in American cement mortar mixed in the proportion of one part of cement to one part of sand, in addition to the prices per cubic yard hereinbefore stipulated to be paid for the same class of masonry laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, the sum of —— ($——) per cubic yard.

(*t*) For all kinds of masonry laid in Portland cement mortar mixed in the proportion of one part of cement to one part of sand, in addition to the prices per cubic yard hereinbefore stipulated to be paid for the same class of masonry laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, the sum of —— ($——) per cubic yard.

(*u*) For all kinds of masonry laid in Portland cement mortar mixed in the proportion of one part of cement to two parts of sand, in addition to the prices per cubic yard hereinbefore stipulated to be paid for the same class of masonry laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, the sum of —— ($——) per cubic yard.

(*v*) For all kinds of masonry laid in Portland cement mortar mixed in the proportion of one part of cement to three parts of sand, in addition to the price per cubic yard hereinbefore stipulated to be paid for the same class of masonry laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, the sum of —— ($——) per cubic yard.

(*w*) For building walk, including all incidental work, the sum of —— ($——) per linear or running foot.

(*x*) For all extra work done by written order of the Boston water board, its actual reasonable cost to the contractor, as determined by the city engineer, plus fifteen per cent. of said cost.

Accompanying this proposal is a certified check for two thousand dollars ($2,000), which it is agreed shall become the property of the city of Boston, if, in case this proposal shall be accepted by the Boston water board, the undersigned shall fail to execute a contract with said city under the conditions of this

proposal within the time provided for by the advertisement for proposals; otherwise said check shall be returned to the undersigned.

No member of the city council, and no person in any office or employment of the city of Boston is directly or indirectly interested in this proposal or in any contract which may be made under it, or in expected profits to arise therefrom; and this proposal is made in good faith without collusion or connection with any other person bidding for the same work.

Name —— ——.
—— ——.
Address ——.

Date ——, 1893.

CITY OF BOSTON.

# BOSTON WATER WORKS.

## CONTRACT AND SPECIFICATIONS FOR BUILDING DAM NO. 5, IN THE TOWN OF SOUTHBOROUGH.

*This agreement*, made and concluded this —— day of ——, in the year one thousand eight hundred and ninety-three, between the city of Boston, by its Boston water board, of the first part, and —— —— in the state of ——, of the second part:

Commencement of Work.

**A.** *Witnesseth*, That for and in consideration of the payments and agreements hereinafter mentioned, to be made and performed by the said party of the first part, and under the penalty expressed in a bond bearing even date with these presents and hereunto annexed, the said party of the second part agrees with the said party of the first part to commence the work herein required to be done, within fourteen days after the signing of this contract and to proceed with the work in such order and at such times, points and seasons, and with such force as may, from time to time, be directed by the engineer, and at his own proper cost and expense, to do all the work and furnish all the materials called for by this agreement, in the manner and under the conditions hereinafter specified.

Completion of Work.

And the said party of the second part hereby agrees to complete all the work called for under this agreement, in all parts and requirements and

dam on the Stony Brook branch of the Sudbury river near the site of Nichol's mill, so called, in the town of Southborough, Mass. The dam to be in accordance with plans marked Dam No. 5, dated June 16, 1893, signed by William Jackson, city engineer, and filed in the office of the city engineer, city hall, Boston. The work will also be built in conformity with these specifications.

These plans show only the general character of the work, and during its progress such working plans will be furnished from time to time by the engineer as he may deem necessary.

**Borings.** The character of the materials to be met with, as shown on said plans, is the result of such examinations as the city of Boston has been able to make; but no guarantee is made as to the accuracy of the borings or test pits or the representations on the plans.

**General Description.** 2. The dam is to be built partly of masonry and partly of earth, approximately on the lines shown; but if the character of the materials or circumstances arise which render it advisable to change the location of the dam or to change the plans of the dam the city of Boston expressly reserves the right so to do without payment of damages to the contractor, but all work actually completed will be paid for as per prices bid for the whole work.

The earth embankments will contain plastered concrete core walls. Water-tight material will be placed next these walls on the water side. The embankments will be protected from wash by linings of riprap or paving. A walk will be built on the top of the dam, and other slops and surfaces covered with soil as directed. The embankments will be separated from the masonry overfall by heavy wing walls. A gate-house with wells and appurtenances as shown will be built next to the north wing wall. The "masonry portion" of the dam will be about 300 feet in length and will be a solid mass of rubble masonry faced with range stones laid in courses.

Where the rock is of poor quality or for other reasons, it may seem to the engineer to be desirable, the core walls both in the center of the embankments and under the masonry section may be carried down deep into the rock.

**Work to be Done**

3. The work to be done in a general way consists in stripping the site of the dam; building up the embankments in layers, and in paving or otherwise protecting their surfaces; doing all blasting, rock and timber work; constructing all masonry; building in all iron work in connection with brick or other masonry; laying pipes through the dam; doing all pumping or other temporary work in connection with the permanent work, and delivering over to said city of Boston the whole structure in a complete condition with the masonry all pointed and with the dam ready to be put into service in accordance with the plans and these specifications.

**Lines, Grades, Levels, Plans.**

All work during its progress and on its completion must conform truly to the lines, grades and levels to be determined and given hereafter by the engineer, and due facilities and such assistance and materials as he may require must be furnished by the contractor without extra charge, and the engineer's marks must be carefully preserved. The work must also be built in accordance with the plans and directions which shall be given by him from time to time, subject to such modifications and additions as said engineer shall deem necessary during the prosecution of the work, and in no case will any work which may be performed, or any materials furnished in excess of the requirements of this contract or of the plans or of the specifications, be estimated and paid for, unless such excess shall have been ordered by the water board as hereinafter set forth.

**Tools and Implements.**

The contractor is to furnish all temporary flumes, all materials and all tools, implements, machinery and labor necessary or convenient for doing all the work herein contracted for, with safety to life and property in accordance with this contract, and within the time specified herein; he will be required to construct and put in complete working order the work herein specified, and is to perform and construct all the work covered by this agreement; the whole to be done in conformity with the plans and these specifications; and all parts to be done to the satisfaction of the city engineer.

**Soil.**

4. The soil is to be removed from the grounds where the dam, embankments and other works

are to stand. Wherever directed by the engineer said soil to be hauled and put in spoil-banks, to remain until required to be placed over the finished surfaces of slopes or embankments. The quantities of soil removed will be measured in the spoil banks and paid for as stipulated in article Q, item (*a*).

The slopes of the embankment are to be covered with soil taken from the spoil-banks; if any additional soil is needed for the work, it shall be obtained and taken from such grounds as may be designated by the engineer, and deposited wherever ordered by him; all soil removed from the spoil-banks, or from such grounds as the engineer may designate, shall be measured in excavation. It will be rolled or otherwise compacted, and paid for as stipulated in article Q, item (*aa*).

All surfaces which are required to be afterwards sodded or seeded are to be covered with soil at least twenty-four inches in thickness.

**Sodding and Seeding.** 5. The embankments of the dam, and such other surfaces as may be designated by the engineer, are to be sodded or seeded with grass seed.

All the surfaces to be sodded or seeded are to be carefully graded and particular care taken to make a true and even bearing for the sods to rest on.

**Sods.** The sods to be of good quality of earth covered with heavy grass, sound and healthy, and not less than one foot square, and generally of a uniform thickness of three inches. These sizes may be altered by the engineer during the progress of the work. The sods will be cut with a bevel on all sides, so that when laid they will lap at the edges; to be properly set so as to have a full bearing on their whole lower surface; to be padded down firm with a spade or wooden bat made suitable for the purpose; each sod is to be pinned with one wooden pin, not less than fifteen inches long, so as to be secured to the ground beneath it, and to be so laid that the upper surface shall conform to the true slope of the bank or ground and to the lines given by the engineer. No lean, poor or broken sods will be allowed in the work, but on the outside edges of the bank sods may be cut to such size and shape as will make a proper

finish to the same. The engineer may alter all the above sizes during the progress of the work.

The sodding that shall have been laid shall be well and carefully sprinkled with water as often as the engineer shall deem necessary.

6. The engineer may specify the kind, quality and amount of seed to be used on all surfaces ordered to be seeded, and he may also direct the manner of seeding, including rolling and watering. **Seeding.**

EARTH EXCAVATION AND EMBANKMENT.

7. Earth excavation is to be made for the foundations, center walls, etc., and for any grading that may be required either above or below the dam, or for any other work in connection with the dam, structures or appurtenances which the engineer may order, but no payment will be made for earth or other excavation unless specifically staked out and ordered by the engineer. The price bid for excavation will cover all excavations by the contractor for his own convenience or for temporary or protecting work, none of which will be measured or estimated by the engineer.

8. Earth excavation is to be made in accordance with the lines established by the engineer, and the price herein stipulated for earth excavation—article Q, item (*c*)—is to include the work of clearing and grubbing the ground of all trees, stumps, bushes and roots, and burning or otherwise disposing of the same; of sheeting and bracing and supporting and maintaining all trenches and pits during and after excavation; of all pumping, ditching and draining; of clearing the excavation of all wood or other objectionable materials, of selecting the materials, and of hauling and of disposing of the excavated materials in making embankments, in filling, refilling and wasting; of rolling and watering, and all other labor and expenses incidental to the handling of the excavated materials. **Excavation.**

9. Whenever, in the opinion of the engineer, the material excavated from the pits and trenches can not properly be disposed of in embankment or for other work at one hauling, it shall be deposited in spoil-banks, and paid for under arti- **Spoil Banks.**

the rock is to be shaped roughly in steps or other form that may be ordered by the engineer.

The price bid for rock excavation is to include the cost of supporting and maintaining the excavations, of pumping and draining, of disposing of the excavated materials as ordered by the engineer, and all other incidental expenses.

**Explosives.** 21. All rock excavation in the wall trenches and at any other place designated by the engineer is to be made with explosives of a moderate power, under his directions, and not with high explosives. Black powder may be ordered by him to be used in special cases.

22. All rock surface intended for masonry foundation must be freed from all loose pieces, and be firm and solid, and prepared as directed by the engineer.

FOUNDATION WORK.

23. The foundation work for the centre walls of the dam and for other structures is to be extended to such depth and in such a manner as shall be ordered by the engineer. In bad bottom, sheet piling, tongued and grooved, may be ordered to be driven or placed on one or more sides of the work. If the material of excavation is such, in the opinion of the engineer, as to require especial precaution, the trenches for the centre wall and for other structures may be ordered extended to a great depth, beyond the indications of the plans. The position of the bed rock being uncertain, it is impossible to indicate the bottom of the core-wall with accuracy, and it is distinctly understood that the lines for the foundation shown on the plans are not guaranteed by the city to be correct.

PROTECTIVE WORK.

24. The contractor will be required at his own expense to take care of all water which may come down the stream during the progress of the work, and to make good any damage done to the dam from freshets or other action of the water or the elements.

TIMBER.

25. Timber may be ordered used for platforms, for permanent sheet-piling, and for other perma-

nent uses. It shall be of the sizes and placed in the manner ordered by the engineer.

26. All timber and lumber so used shall be spruce, sound, straight grained, and free from all shakes, loose knots and other defects that may impair its strength and durability. The price bid for timber shall cover all incidental expenses incurred for labor or for tools or materials used in placing, securing and fastening it.

27. No payment shall be made to the contractor for lumber used for bracing, sheeting, scaffolding and other temporary purposes.

28. All sheeting and other timber work in the trenches and pits shall be removed unless it is ordered left in, in which case such timber shall be paid for as herein stipulated—article Q, item (*e*)—for permanent timber work.

29. The timber to be used for sheet-piling in the foundations and other places may be ordered tongued and grooved. Such timber shall be furnished and placed as ordered, and the price hereinafter stipulated—article Q, item (*ee*)—for tongued and grooved timber is to cover the cost of placing, driving, securing and fastening the same. **Tongued and Groved Timber**

MASONRY.

30. All masonry, except where otherwise specified, shall be laid in hydraulic cement mortar, and shall be built of the forms and dimensions shown on the plans, as directed by the engineer from time to time, and the system of bonding ordered by the engineer shall be strictly followed.

31. All beds and joints must be entirely filled with mortar, and the work in all cases shall be well and thoroughly bonded.

32. Care must be taken that no water shall interfere with the proper laying of masonry in any of its parts. **Water.**

33. All means used to prevent water from interfering with the work, even to the extent of furnishing and placing pipes for conducting the water away from points where it might cause injury to the work, must be provided by the contractor at his own expense. **Pipes.**

34. Under no circumstances will masonry be allowed to be laid in water.

Iron-work.

35. All iron-work, except the sluice-gates, is to be built in the masonry without other compensation than the price herein stipulated to be paid per cubic yard of masonry. The pipes, special castings and other iron work will be furnished and delivered by the city on the site of the dam, and must then be carefully protected, handled and laid by the contractor in a thorough manner as directed by the engineer.

Freezing Weather.

36. No masonry is to be built between the 15th of November and the 15th of April, or in freezing weather, except by permission of the engineer.

All masonry to be amply protected from the action of frost during the winter. The contractor will be required to make good any damage resulting from frost on any portion of the work.

Sprinkling.

37. All fresh masonry, if allowed to be built in freezing weather, must be covered and protected in a manner satisfactory to the engineer, and during hot weather all newly-built masonry shall be kept wet by sprinkling water on it with a sprinkling pot until it shall have become hard enough to prevent its drying and cracking, and if necessary canvass coverings must be provided.

Cement.

38. American cement and Portland cement are to be used. The American cement must be in good condition and must be equal in quality to the best Rosendale cement. It must be made by manufacturers of established reputation, must be fresh and very fine ground, and in well-made casks. The Portland cement must be of a brand equal in quality to the best English Portland cement. To insure its good quality, all the cement furnished by the contractor will be subject to inspection and rigorous tests; and if found to be of improper quality, will be branded and must be immediately removed from the work; the character of the tests to be determined by the engineer. The contractor shall, at all times, keep in store at some convenient point in the vicinity of the work, a sufficient quantity of cement to allow ample time for the tests to be made without delay to the work of construction. The engineer shall be notified at once of each delivery of cement. It shall be stored in a tight building, each cask must be raised several inches above the ground, by blocking or otherwise.

39. Cement is generally to be used in the form of mortar with an admixture of sand, and when so used, its use is included in the price herein stipulated for the various kinds of masonry. For the foundation work, however, Portland cement may be ordered by the engineer in exceptionally wet and difficult places, to be used with or without any admixture of sand for grouting seams or for such other purposes as he may direct. The cost of placing said cement will be paid by the city, the price to be paid to be estimated by the engineer unless otherwise stipulated. Such cement is to be paid for per barrel of four hundred pounds, furnished and delivered by the contractor at the place where it must be used. See article Q, item (*f*).

40. All mortar shall be prepared from cement of the quality before described, and clean, sharp sand. These ingredients shall be thoroughly mixed dry, as follows: The proportion of cement ordered, by measure, with the ordered proportion of sand, also by measure; and a moderate dose of water is to be afterwards added to produce a paste of proper consistency; the whole to be thoroughly worked with hoes or other tools. In measuring cement it shall be packed as received in casks from the manufacturer. The mortar shall be freshly mixed for the work in hand, in proper boxes made for the purpose; no mortar to be used that has become hard or set. If the mortar ingredients are mixed at some distance from the work, water shall not be added until the mortar has been brought to the dam and is ready for use. **Mortar.**

41. The price herein stipulated for the various kinds of masonry is contingent on the use of a mortar made of a mixture of one part in a volume of American cement to two parts of sand. Additional prices are herein stipulated for the use of mortars formed with a different mixture of cement and sand. Article Q, items (*s*), (*t*), (*u*), (*v*).

42. The concrete shall be formed of sound broken stones or screened gravel stones not exceeding two inches at their greatest diameter. All stones in any way larger are to be thrown out. The materials to be cleaned from dirt and dust **Concrete.**

before being used; to be mixed in proper boxes, with mortar of the quality before described, in the proportion of five parts of broken stone to one part of cement; to be laid immediately after mixing, and to be thoroughly compacted throughout the mass by ramming till the water flushes to the surface; the amount of water used for making the concrete to be approved or directed by the engineer. The concrete shall be allowed to set for twelve hours, or more, if so directed, before any work shall be laid upon it; and no walking over or working upon it shall be allowed while it is setting. Article Q, item (*g*).

43. Whenever ordered by the engineer the concrete shall be formed of broken stones not exceeding one inch at their greatest diameter, used in the proportion of three parts of broken stone to one part of cement. Article Q, item (*gg*).

**Plastering.** 44. The up-stream faces of all core-walls, and such other surfaces as the engineer may direct, will be thoroughly plastered with a half inch coat of Portland cement plastering put on in two portions as follows. Next the concrete a thick coating of Portland cement mortar will be put on, mixed in the proportion of one part of cement to one of sand, rubbed to a uniform surface and left rough; over this will be smoothly spread with trowels a coat of neat Portland cement which shall be thoroughly worked to make a perfectly water-tight surface. All plastering will be measured and paid for by the square yard of superficial surface as per article Q, item (*h*).

45. The bricks shall be of the best quality of hardburned bricks; burned hard entirely through, regular and uniform in shape and size, and of compact texture. To insure their good quality, the bricks furnished by the contractor will be subject to inspection and rigorous tests, and if found of improper quality will be condemned, the character of the tests to be determined by the engineer. They are to be culled before laying at the expense of the contractor, and all bricks of an improper quality shall be laid aside and removed; the engineer to be furnished with men for this purpose by and at the expense of the contractor.

**Brick Masonry.** 46. All brick masonry shall be laid with bricks of the quality before described and in Portland

cement mortar mixed one part of cement to two of sand. No "bats" shall be used except in the backing, where a moderate proportion (to be determined by the engineer) may be used, but nothing smaller than "half bricks." The bricks to be thoroughly wet just before laying. Every brick to be completely imbedded in mortar under its bottom, and on its sides. Care should be taken to have every joint full of mortar and all joints shall be pointed.

47. All centering shall be made, put up and removed in a manner satisfactory to the engineer. Centering

48. All stone masonry is to be built of sound, clean quarry granite stone of quality and size satisfactory to the engineer; all joints to be full of mortar, unless otherwise specified. Stone Masonry

49. Paving is to be laid without mortar, and is to be used for portions or the whole of the slopes of the dam embankments, and at any other place that may be designated. Paving.

50. This work is to be measured in accordance with the lines shown on the drawings or ordered during the progress of the work. The stones used must be roughly rectangular; all irregular projections and feather edges must be hammered off. No stone will be accepted which has less than the depth represented on the plans or ordered. Each stone used must be set solid on the foundation of broken stone or earth and no interstices must be left.

51. After the slopes which are to receive the paving have been dressed, a layer of broken stone, nine inches thick or less, is to be spread as a foundation for the paving wherever ordered. The broken stone must be sound and hard, not exceeding two inches at the greatest diameter. Broken stones may be used also wherever the engineer may direct, and paid for under this head. Article Q, item (*l*). The cost of the broken stone used for making concrete is included in the price hereinbefore stipulated for concrete laid. Broken Stones

52. Riprap instead of paving may be used for covering a large portion of the dam slopes, and wherever the engineer may order. It shall be made of stone of such size and quality and in such manner as he shall direct, and must be roughly laid by hand. It will generally be put Riprap.

on in thick layers, and if found cheaper will probably be substituted for paving on the lower slopes of the dam below the berm.

**Rubble.** 53. Rubble-stone masonry is to be used for the central part of the dam, for the wing-walls of the earth embankments, for the gate-house and wherever ordered by the engineer.

It shall be made with sound clean stones of compact texture, free from loose seams and other defects. They must have roughly rectangular forms, and all irregular projections and feather edges must be hammered off before the stones are set. The beds must be good for materials of this class and must present such even surfaces that when lowering a stone on the surface prepared to receive it, there may be no doubt that the mortar will fill all spaces.

After the bed-joints are thus secured, a moderate quantity of spalls can be used in the preparation of suitable surfaces for receiving other stones. No spalling up under a stone after it is laid will be allowed, neither will any grouting or filling of joints be allowed after the stone is set. Especial care is to be taken to have every stone entirely surrounded by mortar.

The quality of the beds is to regulate, to a large extent, the size of the stones used, as the difficulty of forming a good bed-joint increases with the size of the stones. Various sizes must be used.

Generally the largest stones are not to measure more than twenty cubic feet, and they are to be used in the proportion of about twenty-five per cent. of the whole, but they must be omitted partially or entirely if their beds are not satisfactory. It is expected that one quarter of the stones used will be of such size that two men can handle them. The balance to be composed of intermediate sizes. Regular coursing to be avoided.

**Broken Ashlar.** 54. The exposed faces of the wing walls, retaining walls, and of any other rubble work that the engineer may designate, are to be made of broken ashlar with joints not exceeding one-half inch in thickness; the stones not to be less than 12 inches deep from the face, and to present frequent headers. The joints shall be pointed with neat Portland cement. This face work is to be

paid for by the square foot of the superficial area for which it is ordered in addition to the price paid per cubic yard of rubble-stone masonry, but the right is reserved to change this masonry to range work, should it be for the interest of the city so to do. Article Q, item (*n*).

55. The outer faces of the masonry dam, and if found best the gate-chamber and any other masonry that may be designated, are to be made of range stones, as shown on the plans, the stones to be of unobjectionable quality, sound and durable, free from all seams and other defects, and of such kind as shall be approved by the engineer. They shall be pointed with neat Portland cement. **Rangework.**

All beds, builds and joints are to be cut true to a depth of not more than 4 inches, and not less than 3 inches from the faces and to surfaces allowing of one-half inch joints at most; the joints for the remaining part of the stones not to exceed 2 inches in thickness at any point.

56. All cut arrises to be true, well defined and sharp. **Arrises.**

57. Where this class of masonry joins with dimension stone masonry the courses must correspond, and the joining with arches and other dimension stone masonry must be accurate and workmanlike.

Each course to be composed of two stretchers and one header alternately, the stretchers not less than 3 feet long nor more than 7 feet long. **Bond.**

58. The rise of the courses may vary from bottom to top from 30 inches to 15 inches in approximate vertical progression, and the width of bed of the stretchers is not to be at any point less than the height nor less than 24 inches. The headers are not to be less than 4 feet in length. **Courses.**

This class of masonry, including the headers, is to be estimated at 30 inches thick throughout. In no case are the tails of the headers to be estimated. **Measurement.**

59. The coping of the wing walls will be classed as coping stone masonry. The surfaces will be rough pointed to the circular forms given. The capping stones to the posts will be estimated as dimension stone with hammered surfaces. **Coping.**

Prices. 60. The prices herein stipulated for range and broken ashlar stone masonry are to cover the cost of pointing, of cutting chisel drafts at all corners and angles in the work, and of preparing the rock faces; but if any six-cut work is ordered in connection with this class of masonry it shall be paid for at the prices hereinafter stipulated for such work. Article Q, item (*r*).

61. The face bond must not show less than 12 inches lap unless otherwise permitted.

Pointing. 62. The pointing of the faces of all masonry in the dam, gate-house and wings to be thoroughly done with neat Portland cement after the structures are completed, every joint to be raked out therefor to a depth of at least 2 inches, and if the engineer is satisfied that the pointing at any place is not properly done it must be taken out and done over again. The cement is to be mixed in small quantities and applied before its first setting.

Dimension Stone Masonry. 63. Dimension stone masonry must be made of first-class granite of moderately uniform color, free from all seams, discoloration and other defects, and satisfactory to the engineer. The stones shall be cut to exact dimensions, and all angles and arrises shall be true, well defined and sharp. All beds, builds and joints are to be dressed for the full depth of the stone, to surfaces allowing of one-quarter (¼) inch joint at most. No plug-hole of more than 6 inches across or nearer than 3 inches to an arris is to be allowed, and in no case must the aggregate area of the plug-hole in any joint exceed one-quarter of its whole area.

The stone shall be laid with one-quarter (¼) inch joints, and all face joints shall be pointed with mortar made of neat Portland cement, applied before its first setting. All joints to be raked out to a depth of two inches before pointing; the cost of pointing to be included in the price stipulated for cut stone masonry.

Rock-face. 64. In rock face work the arrises of the stones enclosing the rock face must be pitched to true lines; the face projections to be bold, and from 3 to 5 inches beyond the arrises. The angles of all walls or structures having rock faces are to

be defined by a chisel draft not less than 1½ inches wide on each face.

65. In fine hammered work the face of the stones must be brought to a true plane and fine dressed, with a hammer having six blades to the inch. Hammered Work.

For fine hammer-dressing (six-cut work) the price stipulated in article Q, item (*r*), per superficial square foot of dressing will be paid in addition to the price per cubic yard of masonry.

66. No payment will be made for cutting grooves and recesses other than the price paid for the dressing of their surfaces, which are to be fine hammered. Grooves.

67. The contractor will build a walk upon the top of the earthen embankments. It will be 8 feet wide and 1 foot in depth, composed of broken stone 9 inches in depth and a thin layer of selected screenings and binding gravel (as ordered). The surface will be moistened and rolled with a hand roller as directed. The broken stone screenings and gravel used in this walk will not be included in any other measurement. Payment will be made for the finished walk according to the number of linear or running feet it may contain. Walk.

GENERAL CLAUSES.

68. If any person employed by the contractor on the work should appear to the engineer to be incompetent, or to act in a disorderly or improper manner, he shall be discharged immediately on the requisition of the engineer, and such person shall not be again employed on the work. Incompetent Workmen.

69. Any materials condemned or rejected by the engineer or his representatives may be branded, or otherwise marked, and shall, on demand, be at once removed to a satisfactory distance from the work. Materials Branded.

70. Any unfaithful or imperfect work which may be discovered before the final acceptance of the work shall be corrected immediately, and any unsatisfactory materials delivered shall be rejected on the requirement of the engineer, notwithstanding that they may have been overlooked by the proper inspector. The inspection of the work shall not relieve the contractor of any of Imperfect Work.

his obligations to perform sound work, as herein prescribed; and all work, of whatever kind, which, during its progress and before it is finally accepted, may become damaged from any cause shall be removed, and replaced by good and satisfactory work.

Orders Obeyed. 71. Whenever the contractor is not present on any part of the work where it may be desired to give directions, orders will be given by the engineer to, and shall be received and obeyed by, the superintendent or foreman who may have charge of the particular work in relation to which the orders are given.

Laws. 72. In all the operations connected with the work herein specified, all laws or regulations controlling or limiting in any way the actions of those engaged on the works, or affecting the methods of doing the work or materials applied to it, must be respected and strictly complied with; and during the progress of the work the contractor shall provide such precautions as may be necessary to protect life and property.

Clearing up. 73. After the completion of the work the contractor is to remove all temporary structures built by him, and all surplus materials of all kinds from the site of the work, and to leave them in neat condition.

Subletting. H. The contractor agrees that he will give his personal attention to the fulfillment of this contract; and that he will not sublet the aforesaid work, but will keep the same under his control, and that he will not assign, by power of attorney or otherwise, any portion of the said work, unless by and with the previous consent of the water board, to be signified by endorsement on this agreement.

Ways and Means. I. The contractor shall furnish the necessary scaffolding, ways and all necessary means and conveniences for the transfer of the material to its proper place and for its erection. And it is also to be understood that the city shall not be held responsible for the care or protection of any materials or parts of the work until its final acceptance.

Access. J. It is further agreed that the engineer, or his authorized agent and assistants, shall at all times have access to the work during its pro-

gress; and he shall be furnished with every reasonable facility for ascertaining that the work being done is in accordance with the requirements and intention of this contract.

**K.** Should it be found desirable by the water board to make alterations in the form or character of any of the work, the said water board may order such alterations to be made, defining them in writing and drawings, and they shall be made accordingly; *provided,* that in case such changes increase the cost of the work, the contractor shall be fairly remunerated; and in case they shall diminish the cost of the work, proper deduction from the contract price shall be made; the amount to be paid or deducted to be decided by the city engineer. **Alteration.**

**L.** The contractor hereby agrees that he will do such extra work as may be required by the water board for the proper construction or completion of the whole work herein contemplated; that he will make no claims for extra work unless it shall have been done in obedience to a written order from the said water board or their duly authorized agent; that all claims for extra work done in any month shall be filed in writing with the engineer before the fifteenth of the following month; and that, failing to file such claims within the time required, all rights for pay for such extra work shall be forfeited. The price to be paid for all extra work done shall be its actual reasonable cost to the contractor, as determined by the city engineer, plus fifteen per cent. **Extra Work.**

**M.** The contractor is to use such appliances for the performance of all the operations connected with the work embraced under this contract as will secure a satisfactory quality of work and a rate of progress which, in the opinion of the engineer, will secure the completion of the work within the time herein specified. If, at any time before the commencement or during the progress of the work, such appliances appear to the engineer to be inefficient or inappropriate for securing the quality of the work required or the said rate of progress, he may order the contractor to increase their efficiency or to improve their character, and the contractor must conform to such order; but the failure of the engineer to de- **Appliances.**

mand such increase of efficiency or improvement shall not relieve the contractor from his obligation to secure the quality of work and the rate of progress established in these specifications.

**N.** The said contractor further agrees that if the work to be done under this contract shall be abandoned, or if at any time the engineer shall be of the opinion, and shall so certify in writing to the water board, that the said work is unnecessarily or unreasonably delayed, or that the said contractor is willfully violating any of the conditions or agreements of this contract, or is not executing said contract in good faith, or fails to show such progress in the execution of the work as will give reasonable grounds for anticipating its completion within the required time, the said water board shall have power to notify the said contractor to discontinue all work, or any part thereof, under this contract; and thereupon the said contractor shall cease to continue said work, or such part thereof, as the said water board may designate; and the said water board shall thereupon have the right, at their discretion, to contract with other parties for the delivery or completion of all or any part of the work left uncompleted by said contractor, or for the correction of the whole or any part of said work. And in case the expense so incurred by said water board is less than the sum which would have been payable under this contract if the same had been completed by the said contractor, then the said contractor shall be entitled to receive the difference; and in case such expense shall exceed the last said sum, then the contractor shall, on demand, pay the amount of such excess to the said city, on notice from the said water board of the excess so due; but such excess to be paid by the contractor shall not exceed the amount of the security for the performance of this contract.

**O.** The said contractor further agrees that the said water board may, if they deem it expedient to do so, retain out of and amounts due to the said contractor sums sufficient to cover any unpaid claims of mechanics or laborers for work or labor performed under this contract; *provided*, that notice in writing of such claims, signed by

the claimants, shall have been previously filed in the office of the city clerk.

**P.** The said contractor further agrees that he will indemnify and save harmless said city from all claims against said city, under chapter one hundred and ninety-one of the public statutes of Massachusetts, and any laws passed since the public statutes, with reference to liens on buildings and lands, for labor done and materials furnished under this contract, and shall furnish the said water board with satisfactory evidence, when called for by them, that all persons who have done work or furnished materials under this contract, for which the said city may become liable, and all claims from the various departments of the city government, or private corporations, or individuals, for damage of any kind caused by the construction of said work, have been fully paid or satisfactorily secured; and in case such evidence is not furnished, an amount necessary and sufficient to meet the claims of the persons aforesaid shall be retained from any moneys due, or that may become due, the said contractor under this contract, until the liabilities aforesaid shall be fully discharged or satisfactorily secured.

The said contractor further agrees that he will indemnify and save harmless the said city from all suits or actions, of every name and description, brought against the said city for or on account of any injuries or damages received or sustained by any person or persons, by or from the said contractor, his servants or agents, in the construction of said work, or by or in consequence of any negligence in guarding the same, or any improper materials used in its construction, or by or on account of any act or omission of the said contractor or his agents; and the said contractor further agrees that so much of the money due him under and by virtue of this agreement as shall be considered necessary by the said engineer may be retained by the said city until all such suits or claims for damages as aforesaid shall have been settled, and evidence to that effect furnished to the satisfaction of the said engineer.

**Q.** And the said contractor further agrees to receive the following prices as full compensation

for furnishing all the materials, and for doing all the work contemplated and embraced in this agreement; also, for all loss or damage arising out of the nature of the work aforesaid, or from the action of the elements, or from any unforeseen obstruction or difficulties which may be encountered in the prosecution of the same; and for all risks of every description connected with the work; also, for all expense incurred by or in consequence of the suspension or discontinuance of said work as herein specified, and for well and faithfully completing the work, and the whole thereof, in the manner and according to the plans and specifications, and the requirements of the engineer under them, to wit:

(*a*) For the removal of soil excavated and placed in spoil banks, including all incidental work, the sum of —— ($——) per cubic yard.

(*aa*) For the removal of soil taken from spoil banks or from other places and placing on the slopes of the embankment, including all incidental work, the sum of —— ($——) per cubic yard.

(*b*) For sodding, including all incidental work, the sum of —— ($——) per superficial square yard.

(*bb*) For seeding, including all incidental work, the sum of —— ($——) per acre.

(*c*) For earth excavation, including its disposal in embankments and refilling, or as otherwise ordered by the engineer, and all incidental work, the sum of —— ($——) per cubic yard.

(*cc*) For rehandling of excavated materials from spoil banks, and placing, including all incidental work, the sum of —— ($——) per cubic yard.

(*d*) For rock excavation, including its disposal, and all incidental work, the sum of —— ($——) per cubic yard.

(*e*) For permanent timber work, except tongued and grooved timber, placed, including all incidental work, the sum of —— ($——) per thousand feet B. M.

(*ee*) For permanent timber work, tongued and grooved, placed, including all incidental work, the sum of —— ($——) per thousand feet B. M.

(*f*) For Portland cement ordered by the engi-

neer, delivered where ordered on the work, in barrels containing four hundred pounds, including all incidental work, the sum of —— ($——) per barrel.

(*g*) For concrete masonry, in place, formed of five parts of broken stone or screened gravel, to one part of cement, and made with American cement mortar mixed in the proportion of one part of cement to two parts of sand, including all incidental work, the sum of —— ($——) per cubic yard.

(*gg*) For concrete masonry, in place, formed of three parts of broken stone or screened gravel to one part of cement and made with American cement mortar mixed in the proportion of one part of cement to two parts of sand, including all incidental work, the sum of —— ($——) per cubic yard.

(*h*) For plastering all concrete walls with Portland cement, including all incidental work, the sum of —— ($——) per superficial square yard.

(*i*) For brick masonry, laid in Portland cement mortar mixed in the proportion of one part of cement to two parts of sand, and including all pointing, centering, etc., and removing the same, and all incidental work, the sum of —— ($——) per cubic yard.

(*j*) For paving in place, including all incidental work, the sum of —— ($——) per cubic yard.

(*k*) For riprap in place, including all incidental work, the sum of —— ($——) per cubic yard.

(*l*) For broken stone in place (other than that used in making concrete and the walk), including all incidental work, the sum of —— ($——) per cubic yard.

(*m*) For rubble-stone masonry, laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, including all incidental work, the sum of —— ($——) per cubic yard.

(*n*) For face work of broken ashlar, in addition to the price paid per cubic yard as rubble, including pointing in neat Portland cement, and

all incidental work, the sum of —— ($——) per superficial square foot.

(*o*) For facing stone masonry of range stones laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand and pointing in neat Portland cement, including all incidental work, the sum of —— ($——) per cubic yard.

(*p*) For coping laid in place, and pointed in neat Portland cement, including all incidental work, the sum of —— ($——) per linear or running foot.

(*q*) For dimension stone masonry laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, including pointing in neat Portland cement, centering, etc., and all incidental work, the sum of —— ($——) per cubic yard.

(*r*) For fine hammer dressing (six-cut work) the sum of —— ($——) per superficial square foot.

(*s*) For all kinds of masonry laid in American cement mortar mixed in the proportion of one part of cement to one part of sand, in addition to the prices per cubic yard hereinbefore stipulated to be paid for the same class of masonry laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, the sum of —— ($——) per cubic yard.

(*t*) For all kinds of masonry laid in Portland cement mortar mixed in the proportion of one part of cement to one part of sand, in addition to the prices per cubic yard hereinbefore stipulated to be paid for the same class of masonry laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, the sum of —— ($——) per cubic yard.

(*u*) For all kinds of masonry laid in Portland cement mortar mixed in the proportion of one part of cement to two parts of sand, in addition to the prices per cubic yard hereinbefore stipulated to be paid for the same class of masonry laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, the sum of —— ($——) per cubic yard.

(*v*) For all kinds of masonry laid in Portland cement mortar mixed in the proportion of one part of cement to three parts of sand, in addi-

tion to the price per cubic yard hereinbefore stipulated to be paid for the same class of masonry laid in American cement mortar mixed in the proportion of one part of cement to two parts of sand, the sum of —— (\$——) per cubic yard.

(*w*) For building walk, including all incidental work, the sum of —— (\$——) per linear or running foot.

(*x*) For all extra work done by written order of the Boston water board, its actual reasonable cost to the contractor, as determined by the engineer, plus fifteen per cent. of said cost.

**R.** And it is agreed that payment for the work embraced in this contract shall be made in the following manner:

A payment will be made, on or about the first day of each month, of 85 per centum of the value of the work completed in place by the contractor on the fifteenth of the previous month, as estimated by the engineer.

*Provided, however,* that the making of such payment may be deferred from month to month, when, in the opinion of the engineer, the value of work done since the last estimate for payment is less than one thousand dollars.

The said contractor further agrees that he shall not be entitled to demand or receive payment for any portion of the aforesaid work or materials, until said work shall have been completed to the satisfaction of the city engineer, and the said city engineer shall have given his certificate to that effect; whereupon the said city will, within forty days after such completion, and the delivery of such certificate, pay the said contractor the whole amount of money accruing to the said contractor under this contract, excepting such sum or sums as may be lawfully retained by said city.

*Provided,* that nothing herein contained be construed to affect the right hereby reserved of the said water board to reject the whole or any portion of the aforesaid work, should the said certificate be found or known to be inconsistent with the terms of this agreement, or otherwise improperly given.

**S.** The parties hereto further agree that this contract shall be in writing, and executed in triplicate, one of which triplicates shall be kept by the said engineer, one to be delivered to the city

auditor of said Boston, and one to the said contractor; that this contract shall be utterly void as to the said city if any person appointed to any office, or employed by virtue of any ordinance of said city, is either directly or indirectly interested therein.

And the said contractor further agrees that he will execute a bond in the sum of one hundred thousand dollars ($100,000) and with such sureties as shall be approved by the said Boston water board, to keep and perform well and truly all the terms and conditions of this contract on his part to be kept and performed and to indemnify and save harmless the said water board as herein stipulated.

**T.** And it is also to be understood and agreed that, in case of any alterations, so much of this agreement as is not necessarily affected by such alterations shall remain in force upon the parties hereto.

**U.** And the said contractor hereby further agrees that the payment of the final amount due under this contract and the adjustment and payment of the bill rendered for work done in accordance with any alterations of the same, shall release the city from any and all claims or liability on account of work performed under said contract or any alteration thereof.

*In witness whereof* the parties to these presents have hereunto set their hands the year and day first above written.

| | |
|---|---|
| *The City of Boston, by its Boston Water Board.* | —— ——. <br> —— ——. <br> —— ——. |
| | —— ——. <br> —— ——. <br> —— ——. <br> —— ——. |

SIGNED in the presence of

—— ——.<br>
—— ——.<br>
—— ——.

*Know all Men by these Presents,*

That we —— —— —— —— are held and firmly bound unto the CITY OF BOSTON, in the sum of —— dollars, to be paid to the CITY OF BOSTON, or its certain attorney, its successors and assigns, for which payment, well and truly to be

made, we bind ourselves, our heirs, executors and administrators, jointly and severally, firmly by these presents.

*The condition of this obligation is such that* if the above-bounden —— —— —— —— shall well and truly keep and perform all the terms and conditions of the foregoing contract for building dam No. 5, in the town of Southborough on —— part to be kept and performed, and shall indemnify and save harmless the said CITY OF BOSTON, as therein stipulated, then this obligation shall be of no effect; otherwise it shall remain in full force and virtue.

*In witness whereof* we hereto set our hands and seals on this —— day of ——, in the year eighteen hundred and ninety-three.

—— ——.
—— ——.
—— ——.
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## 177. SPECIFICATIONS FOR THE STRUCTURAL IRON WORK

OF A

## HOTEL BUILDING,

TO BE ERECTED ON THE SOUTHWEST CORNER OF 34TH STREET AND 5TH AVENUE FOR JOHN JACOB ASTOR.

H. J. HARDENBERGH,
Architect,
New York.

PURDY & HENDERSON,
Consulting Engineers,
New York and Chicago.

MAY, 1895.

In order to understand the business relations involved in the following specifications, some explanation of them is necessary.

Messrs. Purdy and Henderson, the consulting engineers, are under contract with Mr. H. J. Hardenbergh, architect, to furnish those parts of the plans and specifications for the building which relate to the iron and steel frame work. They are also under contract with Mr. Downey, the agent of the owner, to prepare all the shop drawings, to supervise the inspection, to superintend the erection of the steel frame work, to check all bills rendered by the contractor for this portion of the work, and, in general, to see that all the contracts relating to this part of the building are faithfully fulfilled. The contract for the iron and steel work was let on a pound basis erected. A separate set of specifications were prepared for the inspection of the work, and also one for the use of the computers and draftsmen in preparing detail plans. It will thus be seen that the consulting engineers are under contract to do a great deal more in this matter than is usually expected of the architect, and much more, therefore, than the architect could afford to pay for, if all this service had to be remunerated out of his professional fees. In the most common practice, the owner checks his own bills, pays the contractor for the shop drawings and divides the remaining portion of this additional service with the architect. Only a small portion of the additional fee paid the engineer by this arrangement is consequently an added expense. It is important that consulting engineers should make contracts with the owner for the additional detail work and supervision as well as with the architect for the preparation of the general plans. This kind of a double connection is desirable and likely to secure the most satisfactory service.

The steel construction described in these specifications is that for a new hotel adjoining The Waldorf on the north, corner 34th street and Fifth avenue, New York city. The building is in plan 350 feet by 100 feet, and is sixteen stories high above the sidewalk, with basement and sub-basement, extending 35 feet below ground. It is the largest steel constructed building ever designed, containing over 10,000 tons of structural iron. The exterior of the building is finished with stone to the height of three stories above the sidewalk, and with

brick, with terra cotta trimmings, above that line. The construction involves many unusual conditions, such as a ballroom on the second story 100 feet long, and 85 feet wide, with vaulted ceiling reaching to the fifth floor. The floors above this great room, and also the roof, are carried on two trusses extending through four stories, the total load carried by the two being about nine million pounds. The columns in the walls around this ballroom are from 60 to 70 feet in length, and some of them carry over three million pounds each. There is also a large dining room on the first floor, which necessitates the use of very heavy trusses, and difficult and costly work. The spaces between the columns are unusually long, 35 and 40 feet being common, thus requiring an unusual quantity of plate girder work. In several other places in the building, rooms extend through two stories, and the roof on three sides has a Mansard slope fifty feet in height, with large towers on the three street corners. All the details have been worked out with great care, and the business relations of the engineer of construction to both the architect and the owner are considered ideal.

*Specifications Explained:* These specifications are supplemental to the contract already entered into for the constructural iron and steel work of this building, between —— ——, —— ——, parties of the first part,[1] and —— ——, —— ——. parties of the second part. They are the specifications referred to in the first clause of said contract, and which are to be considered a part of that contract.

These specifications are intended to cover all the structural iron work in said building. They are intended to co-operate with the drawings for the same, both those furnished by the architect and those furnished by the engineers as hereinafter specified, and what is called for by either, is as binding as if called for by both. They are intended to describe and provide for a finished piece of work. The contractor will understand that the steel construction herein described is also to be complete in every detail, and in every portion of the work, and all material entering into it is to be first-class, and he will be expected to thoroughly understand the construction and to fully

[1] Mr Astor's agent, who stands as the party of the first part in these specifications, is Mr. John Downey, and he is so named in various parts of the document.

inform himself in regard to any points that he may not clearly understand, for what is herein intended to be described, viz.: The complete and perfect construction of the building is the thing required. When necessary or desirable, he must apply to the architect or the engineers for further details or specifications during construction or before proceeding with his work.

*Requirements Outlined:* This contractor must furnish and set all the iron and steel shown or referred to in these specifications and called for by the said drawings hereinbefore referred to, and when the erection is completed, he must remove all the materials used in performing the work. He must furnish in all cases the exact sections, weights and kinds of material that are called for, and he must follow exact details, methods and instructions called for by these specifications and said drawings. He must set the iron work as fast as may be considered practical in the judgment of the architect, always keeping at least one story in advance of the masonry. He will be expected to give this work his personal supervision, or have a capable man at all times to take care of it. He must also do all the cutting and fitting that may be required in his work to receive the work of other contractors.

*Reference in Case of Dispute:* Should any difference of opinion or dispute arise in relation to the meaning of these specifications, or of the said drawings furnished by either the architect or the engineers as hereinafter specified, reference must be made to the engineers, but if their decision is not satisfactory appeal may be made to the architect, whose decision on all such points shall be final and conclusive.

*Drawings:* The general dimensions, arrangement and sections required for the structural iron work herein specified, are shown on the general structural iron drawings prepared and furnished by the architect, and included in pages —— to ——, inclusive.

The sections given are those of the Carnegie Steel Company's manufacture. In general, these drawings are made to scale, but scale dimensions must never be used. These drawings, together with these specifications, are the property of the architect, to whom all copies must be returned on the completion of the work. Detail or shop drawings, including drawings of every part and piece of the work, with all the lists, schedules, indexes, erection plans or other directions necessary for the proper manufacture, finish and erection of the work covered by these specifications, and the said general drawings prepared by the architect, will be made and furnished by the engineers.

Blue prints of the shop drawings, lists and schedules, as many copies of each as are necessary, but not more than five, will be furnished to the contractor for his use in the manufact-

ure of the material. Another complete set of these prints, together with one complete set of prints of the erection drawings, will be furnished to the contractor for use in erection. One complete set of all the drawings, plans, lists and schedules will be furnished to the inspector. All the above-mentioned prints will be furnished by the engineers, free of expense. Additional prints of any of these drawings may be taken by said contractor or inspector, if desired, at their own expense, but originals taken from the office for that purpose must be promptly returned.

*Orders:* All materials required to be furnished or work to be done under these specifications or by the said general structural iron drawings, prepared by the architect, will be ordered by the engineers from time to time with the shop drawings, lists, schedules, etc., for the same, as fast as they can be prepared, and the contractor for the structural iron work must order no material and perform no work under these specifications until he has received the said detail drawings, lists and schedules for the same. Bolts or other material used temporarily for erection purposes are not included in this specification.

*Extras and Bills:* No additional work or material, over and above what is called for by said detail drawings, lists and schedules, prepared and furnished as hereinbefore provided, will be allowed unless ordered by the architect in writing. When said detail drawings, lists and schedules are received by the contractor, they must be immediately examined to determine whether the material and work called for by the same may be properly classified in the price classification contained in the contract hereinbefore referred to, and of which these specifications are considered a part; or, in any supplemental agreement that may be made to said contract. In case either or both may not be properly classified, in said price classification, the engineers must be promptly notified of the fact in writing, and a copy of such notification must also be sent to the architect. If no reply, verbal or written, to such notification is received within three days, a second notification must be sent the same as the first, but, in any case, the work called for by such detailed drawings, lists or schedules must proceed without delay, unless the contractor shall receive written instructions to the contrary from the architect or engineers.

No bill for extra work ordered by the architect as herein provided, or not called for by said drawings, lists or schedules will be approved by the architect unless it is rendered immediately upon the completion and acceptance of said work. All bills for material or work not properly included in the price classification hereinbefore referred to, must be made separate

from the bills for work and material properly covered by said price classification. All bills must be made sufficiently in detail to permit of their ready verification. The originals of all bills must be sent to the engineers, Purdy & Henderson, and exact duplicates must, at the same time, be sent to John Downey, parties of the first part in the contract hereinbefore referred to.

*Building Laws:* This contractor must comply with all municipal or corporation ordinances and the laws and regulations relating to buildings in the city of New York.

*Risks:* This contractor will be liable and responsible for any damage to life, limb or property that may arise or occur to any party whatever, either from accident or owing to his negligence, or that of his employees during the operations of constructing or completing the works herein specified.

*Rubbish:* This contractor must remove from the premises all rubbish arising from his operations as the work proceeds and at completion of same.

*Signs:* No signs of any description will be allowed to be placed on or about the building or premises.

*Co-operation and Cleaning Up:* This contractor must cooperate with the contractors for the other parts of the building, so that when completed it shall be in accordance with the architect's design and a complete and perfect piece of work. He must arrange and carry on his work in such a way that the other contractors shall not be delayed, subject always to the architect. When his work is finished he must remove from the premises all the tools, apparatus, machinery, scaffolding and the debris pertaining to his part of the work, and leave the job free from all obstruction.

*Kind of Material Required:* All material required for the trusses, and all the material required for the flanges of riveted girders must be open hearth steel.

All other material required for riveted members, and the beams and channels used in the floors with their connections, may be made of Bessemer steel, unless in special cases, it shall be otherwise specified.

Pins over five inches in diameter must be of forged steel.

All machine driven rivets must be of steel.

Tie rods, bolts, anchors, lateral ties and all hand driven rivets must be of wrought iron.

Bearing plates in masonry, bases under columns, separators, brackets under plates and filler blocks more than 1½ inches thick, must be made of cast iron.

Shoes for trusses and column blocks where required must be made of cast steel.

*Character and Finish of Materials:* All the steel used in this building must comply with the following specifications:

| | Medium Steel. | Soft Steel. |
|---|---|---|
| Maximum ultimate strength in lbs. per sq. in. | 68,000 | 60,000 |
| Minimum ultimate strength in lbs. per sq. in.. | 60,000 | |
| Minimum elastic limit in lbs. per sq. in. .... | 32,000 | 30,000 |
| Minimum percentage of elongation in 8 inches | 22% | 26% |

Test pieces of medium steel must bend cold 180 degrees about a diameter equal to the thickness of the piece without any sign of fracture on the convex side of the bends. Test pieces of soft steel must bend cold 180 degrees flat without any sign of fracture on the convex side of the bend. They must also stand the same bend after being heated to a light cherry red and quenched in water whose temperature is 82 degrees Fahrenheit.

Soft steel must be used for rivets and medium steel for all other material. All steel must have a smooth surface and must be free from all faults or defects of any kind or of any indication of unsoundness. Each piece must be straight, free from wind and of proper section. A variation in weight either way of more than 2 per cent. from that specified shall be cause for rejection.

Eye bars used in trusses must comply with the following specifications in full size tests:

| | |
|---|---|
| Ultimate strength in lbs. per sq. in. not less than............... | 58,000 |
| " " " " " " " " more " ............... | 66,000 |
| Elastic limit in lbs. per square inch not less than................ | 29,000 |
| Elongation in 2 ft. length of bar nearest fracture ... ............ | 15% |
| Reduction of area............................................ | 40% |

The fracture must take place in the body of the bar and must be generally silky. The mill requirements for material for eye bars must be as specified for by the manufacturers of the bars.

All wrought iron used in this building must have an ultimate strength of not less than 48,000 lbs. per square inch, an elastic limit of not less than 26,000 lbs. per square inch, and an elongation of 20 per cent. in 8 inches. The wrought iron required for bolts and rivets must be so ductile that test pieces will bend cold 180 degrees flat without any sign of fracture on the convex side of the bend. All the wrought iron must be perfectly welded in rolling, fibrous, uniform and free from all defects. Each piece must be straight and of proper section.

All the cast steel used in this building must have an ultimate strength of not less than 60,000 lbs. per square inch, an elastic limit of not less than 32,000 lbs. per square inch, and an elongation in 8 inches of not less than 15 per cent. All castings must be annealed and all test pieces must be cast as coupons and detached after annealing.

All the cast iron used in this building must be tough gray iron, free from cold shuts, blow holes or other serious defects. Its quality must be such that sample bars 1 inch square cast in sand moulds must be capable of sustaining on a clear span of 4½ feet a central load of 500 pounds when tested in the rough bar.

*Painting:* All iron must receive a coat of pure raw linseed oil at the rolling mills just before being loaded on the cars.

The covered surfaces (surfaces in contact and surfaces enclosed) of all parts of riveted members must receive one good coat of graphite paint, after the pieces are punched and before they are assembled. All finished members must receive one complete coat of the graphite paint before they are taken from the shop or exposed to the weather. All surfaces that can be reached must have one coat of the graphite paint after erection. All truss members must have two coats of paint in the shop and the enclosed surfaces of these members must have the two coats before they are assembled.

Foundation beams and connections must have two coats of paint at the shop. All bolts used in erection and remaining permanently in the building must be dipped in graphite paint before being placed in position.

All pins and bored pin holes or other planed surfaces in the trusses must be coated with white lead and tallow before leaving the shop.

All painting must be done on dry surfaces and preferably warm ones. All dirt and foreign matter of any kind must be removed from the iron before painting. All scale must be removed from finished members before painting the first coat in the shop. All scale must be removed from material required for the trusses before it is oiled at the rolling mill.

The paint used must be the superior graphite paint, prepared and mixed by the Detroit Graphite Manufacturing Company, of Detroit, Michigan.

*Inspection:* The inspection hereby provided will be made by inspectors employed by John Downey.

The contractor for the structural iron must furnish full and ample means for the inspection of all the materials called for by these specifications, and of all the work required in fitting such materials for erection; and to this end, he shall admit the architect, engineers and inspectors to any part of the mills or

shops where work under these specifications is being carried on.

To secure proper material, as herein specified, one pulling test must be made from every heat or blow of steel or rolling of iron, and one bending and one quenching test; when such requirements are specified, if these are satisfactory, the whole will be accepted. If they are not satisfactory, others may be made as the inspector may deem expedient. All test pieces must be prepared at the expense of the contractor for the structural iron. The test pieces of rolled steel and wrought iron must be cut out of finished material, and must not be less than ½ square inch in section. They must be at least 10 inches long between fillets when turned down. When possible they must be cut from the full thickness of the section, from which the tests are taken. The method of selecting test pieces for material for eye bars must be as required by the manufacturer of the bars.

The number of test pieces of cast steel must be fixed by the inspector.

Full sized tests of eye bars must be made as required by the architect or engineers. Test bars for such tests will be selected by the inspector from the lot after forging and before boring, the results of the test to determine the acceptance or rejection of the entire number which the test bar represents. Other full sized tests must be made if required.

The material used for all full sized tests will be paid for at cost, less the scrap value of the material to the contractor when the pieces are tested to destruction, and the test proved satisfactory; otherwise it must be solely at the cost of the contractor. The use of testing machines capable of testing both specimens of material and the full sized members, together with all necessary assistance in handling and operating the same, must be furnished by the contractor free of all expense.

All surfaces of all materials must be carefully examined by the inspectors, and all pieces that are of full section—free from flaws—straight and in every way satisfactory, must be accepted. This inspection will not, however, prevent the rejection of any piece at any later time, but before it is riveted in place in the building, if it is discovered that the piece is in any way unsuitable. Ample assistance must be given by this contractor to the inspector in making this examination.

All material manufactured under these specifications must be tested and examined as herein provided before the same is oiled or loaded on the cars for shipment from the mill, and as soon after rolling as may be convenient for the mill, and failure to comply with these specifications will be sufficient cause for the rejection of the material.

The inspection in the shop must, in general, cover the iden-

tification of material, the accuracy of work, and fulfillment of specifications and drawings in every respect, and reports of finished weights and progress of the work, in all of which the inspector must have ample opportunity to do his work. All rejected material must be made good to the satisfaction of the inspector.

All long measurements in the shop made by the inspector, must be made with a steel tape which must be compared with the shop's standard measure to assure their agreement.

In case of any disagreement between the inspectors and the contractors regarding the inspection, appeal may be had to Purdy & Henderson, Consulting Engineers, but their decision shall be final.

*Beams:* In general not more than 1/8 of an inch will be allowed by the drawings for clearance at each end of beams connecting to beams and not more than 1/4 of an inch at each end of beams connecting to columns. All beams supported by connection angles riveted to the webs when finished, must measure out to out of such connection angles, not more than the length given on the drawings, and not more than 1/8 of an inch less than that length. All beams connecting to columns may be 1/2 inch shorter than shown on the drawings, but must not be longer.

All open holes must be true to the drawings, and an error in the distance from end to end, between the open holes in the flanges at the ends of beams of more than 1-16 of an inch must not be approved bv the inspector.

Where connections are marked standard, the standards adopted for this particular job must be used. Beams or other material used in floor construction, excepting bent plates used in connections, must not be heated for bending, cutting or fitting, unless so marked on the drawings.

Beams split or permanently injured by work in the shop must not be used.

Beams which are required to be bolted together with separators in the building, must be assembled and bolted together in shop when practicable.

*Columns:* The distance from the center of the columns out to the open holes required for the connection of beams, must be verified by the inspector. If, on account of the material overrunning in weight or on any other account, these distances are wrong more than 1-16 of an inch, the error must be remedied, as the inspector may desire.

All columns must be milled or ground at each end to a smooth bearing surface at right angles to the axis of the column, and the inspector must verify from time to time, the adjustment of the machinery used in this work.

All columns must be exactly true to length, and any discrepancies in such lengths of more than 1-32 of an inch, must be reported promptly to the engineers. If more than 1-32 of an inch too long, they must be milled shorter.

Where columns coming over each other are designed to have the same exterior dimensions, a filler about 1-32 of an inch thick must be put under the splice plates where they are riveted to the columns. These fillers must cover the entire area covered by the splice plates. They will not be drawn on the drawings, but will be noted in the bill of material on each drawing where required.

Columns must all be straight and out of wind.

*Riveted Girders:* Web plates must be arranged so as not to project above or below the flange angles. The lines showing the edges of such plates will be omitted from the drawings.

In general, all stiffener angles must fit tight at both ends.

Open holes in flanges must have the same accuracy required for beams.

All riveted girders must be out of wind before leaving the shop.

*Trusses:* Eye bars must be entirely free from flaws and of full section. The heads must be so proportioned that the bars will break in the body of the original bar and the process of manufacture and the form of the head must be subject to the approval of the engineers. No welding will be allowed in the body of the bars. They must be perfectly straight before boring and the pin holes must be centered through the center line of the bar. The lengths back to back of pin holes must not vary more than 1-64 of an inch from the figured lengths when the bars are 20 feet long or less; not more than 1-32 of an inch when more than 20 feet long. Bars which go side by side in the trusses must be so perfectly bored that the pins will pass through the holes at both ends without driving when the bars are placed in a single pile. The holes must not be more than 1-32 of an inch larger than the pins. All eye bars must be annealed.

Compression members must have all butting ends planed smooth and exactly square to the center line of the member, and they must be assembled in the shop for the fitting of the splice plates and to assure perfect contact throughout. Such members must be entirely free from twists or bends and all work must be neatly finished and first-class in every respect. Pin holes must be bored 1-32 of an inch larger than the pins, exactly perpendicular to a vertical plane passing through the center line of each member, when placed in a position similar to that which it should occupy in the finished structure.

Pins must be turned straight and smooth and to exact size.

*Castings:* The cast bases required in the column must be planed smooth on top and to exact dimensions. All holes for the bolts connecting to the columns must be drilled also to the exact measurements given, and the holes in the other castings, both steel and iron, must be drilled when so marked. All surfaces marked planed must be planed smooth and true for a perfect bearing as designed.

*Rivets:* Drifting that is liable to injure the material must not be allowed anywhere in erection.

Shop rivets must be machine driven as far as possible.

Rivet heads must be concentric with the necks of the rivets and all rivets when driven must completely fill the holes and be tight.

Rivets will be used in erection wherever possible.

All rivets must be uniformly heated.

Holes that do not match sufficiently to admit the rivet without drifting, in assembling work in the shop, must be reamed.

All riveting must be done to the satisfaction of the engineers.

*Erection:* If beams are used in the construction of the foundations, the contractor for the structural iron must put them in position, both as to plan and as to height, using a surveyor's level for the purpose, but the grouting and covering of the beams will be done by the contractor for the masonry.

The outside building lines will be given, but the contractor for the structural iron must determine and fix the interior lines, and each cast base must be set in its exact position, both as to alignment and to height, supported on wooden wedges, before the bedding is run in. The center of each base must be true to the column center, as given on the plans, within 1-16 of an inch, and its height must be adjusted exactly, using a surveyor's level and referring to a fixed bench mark. Each base must be bedded with a Portland cement grouting, by pouring the same through the center until all the spaces under and inside the base are filled. The cement must be of some imported brand which must be approved by the architect, and the sand must be clean and sharp and fine. The two must be mixed dry in equal quantities in a box—all that is required for one base at one mixing. Enough water must then be added to make the whole just flow under its own weight. The whole operation of mixing and setting must be done as rapidly as possible. After the bases are set their heights will be inspected by the engineers, and if they are found to vary more than 1/8 of an inch from the correct height they must be taken up and reset.

The use of iron sledges in driving or hammering beams or columns or other structural iron will not be allowed where it can be avoided. Wooden mauls must be used wherever their

use is possible. Care must also be exercised to prevent the material from falling or from being in any way subjected to heavy shocks.

Especial care must be used to keep the columns plumb and in proper line during erection, and they must be plumbed to the satisfaction of the architects and engineers as often as may be desired. In case the columns are not kept plumb the entire work of erection shall stop at the written order of the architect to that effect, and the measures to be employed to remedy the defect must be approved by the architect before the erection proceeds.[1]

The sections of columns, truss members, beams or girders must nowhere be cut without first obtaining the approval of the engineers.

Every failure of the material to come together properly must be noted and reported daily to the engineers. If any serious difficulty occurs during erection, it must be reported to the engineers before any unexpected measures are used to meet the difficulty.

The plan or scheme for the erection of the trusses, and the material connected to the trusses must be submitted to the engineers, before the iron work is erected above the ground floor, for their approval.

Pilot nuts must be used in entering all pins.

After the truss members are put in position, before they are materially shadowed by temporary flooring or any other construction, and after all surfaces are thoroughly dried by the heat of the sun, they shall be protected by waterproof canvas, tarred paper, or other materials from further exposure to the weather. Such protection to continue until those parts of the building are under the cover of the other construction of the building. Such protection is desired to prevent water from lodging and remaining in the concealed parts of the work. Any inaccuracy in the matching of the holes in the column splices must be removed by reaming and not by drifting.

Temporary timber bracing must be put in the building wherever required by the architect or the engineers.

The entire work of erection must be done to the satisfaction of both the architects and the engineers.

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[1] Probably the worst practice in the erection of architectural iron work is the very common use of shims in the joints between the successive column sections, thus concentrating the loads on the opposite sides of the cross-section. The columns are usually kept plumb in this manner, but the practice is extremely vicious, and should not be allowed. If the faces of the ends are properly planed or milled off, and the base plate is set exactly level, it will not be necessary to use shims. The greatest difficulty is in setting the bed plate in a truly horizontal plane. The ordinary carpenter's level is not sufficiently delicate for this purpose. These specifications are not explicit on these points.—AUTHOR.

**178. Specifications for the Machinery and Track Construction of an Electric Railway.** The following specifications for the machinery for an electric railway were prepared by Mr. B. J. Arnold, consulting electrical engineer of Chicago, for the St. Charles Street Railroad Company, of New Orleans, in 1895.

The specifications for track construction were prepared by Mr. Richard McCulloch, M. E., engineer of various street railroads in St. Louis. Both are thought to be the best of their kind, and are here added in the second edition of this work:

In General. **179. Specifications for Engines.** The engines that are purchased under these specifications will be erected in complete running order on foundations furnished by the purchaser in the power house of the railroad company, located on the switch of a steam railroad at New Orleans, La.

Sizes. Propositions will be considered on each of the following sizes and types of engines:

*Proposition No. 1.* On three 250 horse power self-contained compound condensing tandem or cross engines. Each capable of delivering 250 horse power to its generator, when running at a speed of 150 revolutions per minute at a piston speed of not less than 550 feet nor more than 700 feet per minute, with an initial pressure of 125 pounds per square inch in the steam chest of the high pressure cylinder. The valve motion of each engine to be capable of cutting off automatically from naught to three-quarter stroke.

Each engine to be provided with a cast iron bed plate which shall cover the entire top of the foundations and have a projecting arm or extension of sufficient size to carry the electric generator which may be purchased to be direct-connected to the engine.

The point of cut-off is not specified, but the contractor shall state in his proposition what economy in water consumption he will guarantee his engine to perform when working at the above initial steam pressure and exhausting into a vacuum of 12 pounds below atmosphere, in accordance with the conditions for a test hereinafter mentioned.

By horse power is meant actual power delivered by engine to the generator, and not indicated horse power in the steam cylinders.

*Proposition No. 2.* On three engines of the same horse power, design, conditions and guarantees, but to run at 250 revolutions per minute.

*Proposition No. 3.* On three engines of the same design, but built to deliver 200 horse power each to the generator at a speed of 150 revolutions per minute. Same conditions and guarantees as Proposition No. 1.

*Proposition No. 4.* On three engines of 200 horse power each to run at 250 revolutions per minute. Same design, conditions and guarantees as Proposition No. 1.

*Proposition No. 5.* On three 250 horse power compound condensing cross or Tandem or releasing valve type of engines, designed to run at a speed of 100 revolutions per minute, to be direct connected to generators, which will be mounted on the engine shaft between out-board bearing and the fly-wheel. Same conditions and guarantees as Proposition No. 1.

*Proposition No. 6.* On three 250 horse power Corliss or releasing valve engines similar to those called for in Proposition No. 5, but to run at 80 revolutions per minute. Same conditions and guarantees as Proposition No. 1.

*Proposition No. 7.* Three 200 horse power Corliss or releasing valve type of engines, similar to those called for in Proposition No. 5, but to run at 100 revolutions per minute. Same conditions and guarantees as Proposition No. 1.

*Proposition No. 8.* Three 200 horse power Corliss or releasing valve type of engine, similar to those called for in Proposition No. 5, but to run at 80 revolutions per minute. Same conditions and guarantees as Proposition No. 1.

*Proposition No. 9.* On one 500 horse power Tandem compound condensing Corliss or releasing valve type of engine to run at a speed of 80 revolutions per minute, and one 250 horse power Tandem compound condensing Corliss or releasing valve type of engine to run at 80 revolutions

per minute. Same conditions and guarantees as Proposition No. 1.

The 500 horse power is to be a center crank engine and so arranged as to carry a generator on each side.

The 250 horse power engine is to be a side crank engine and carries the generator on but one side. The frame, main working parts and low pressure cylinder of this engine shall be designed extra heavy so that high pressure steam can be admitted to the low pressure cylinder, so as to practically double the power of the engine in case of an emergency. Suitable pipe connections and an auxiliary throttle valve will be made to the live steam pipe by the contractor. The receiver and all receiver connections will also be built strong enough to sustain the extra pressure.

*Proposition No. 10.* On one 400 horse power Tandem compound condensing Corliss or releasing valve type of engine, designed to run at a speed of 80 revolutions per minute, and one 200 horse power Tandem compound condensing Corliss or releasing valve type of engine at 80 revolutions per minute. Same design of engine as called for in Proposition No. 9, and to fulfill the same gurantees as called for in Proposition No. 1.

*Cross Compound Engines.* The bidders shall also submit figures on cross compound engines under Propositions Nos. 1 and 5.

**Regulation.** All engines furnished shall be provided with governing mechanisms which shall be capable of automatically varying the point of cut-off from naught to three-quarter stroke, as the load requires, and of controlling the speed within reasonable limits. The bidder shall state his guarantee on regulation with the engines ranging from half load to full load, and from full load to no load.

All Corliss or releasing valve engines shall govern on both high and low pressure cylinders.

**Fly Wheels.** All engines furnished will be provided with fly wheels instead of belt or band wheels, and the specifications for each engine shall state the diameter and weight of the wheels which the contractor proposes to furnish. It should be remembered by the bidder that these engines are de-

signed for electric railway work, and that the fly wheel should be proportioned for such work.

The condensers and air pumps will be furnished by the purchaser but in case the Corliss engines running not over 100 revolutions per minute are purchased, it may be desirable to drive the boiler feed, air and circulating pumps direct from a rock shaft driven from the cranks or cross-heads of the engines, and the bidder will state how much additional will be charged on Propositions 5, 6, 7, 8, 9 and 10 for such addition. He will state in a general way how he proposes to build the pumps. **Condensers.**

He will also state how much additional will be charged on each proposition in case he furnishes an independent jet or surface condenser with each engine and all necessary pipe work to connect the condensers with the engines. The steam and water connections to be brought to the condensers by the purchaser.

Each engine will be provided with suitable oil cups or lubricating devices, and each steam cylinder provided with a sight feed cylinder lubricator and one hand pump. **Lubricating Devices and Tools.**

In case of side crank engines the cranks will be provided with a separate floor stand and return oiling tube to be the center of the crank pin.

One complete set of brass oil cans and tray for the same shall be considered a part of each proposition, together with all necessary wrenches, etc., for properly taking care of the engines.

Each engine will be provided with a throttle valve on the high pressure cylinder and have a flange fitted to the exhaust opening, threaded to receive the proper sized exhaust pipe. **Throttle Valve**

Each engine will be provided with a complete set of nickel plated gauges, having 12-inch dials, of the Ashcroft, Crosby or Schaffer & Budenberg manufacture, or others equally as good, consisting of the following: **Gauges.**

One steam gauge.

One vacuum gage.

One compound receiver gauge.

Each receiver shall be provided with an automatic safety valve which will relieve the receiver of extra pressure. **Safety Valve.**

Indicator. Each proposition shall include one Crosby, Tabor or Thompson steam engine indicator.

Foundation Bolts. The contractor will furnish a complete set of foundation bolts with nuts and washers for each engine. These bolts to be delivered at the power house site within thirty days from the date of the awarding of the contract.

Test. The engines to be tested as follows. First, on a constant load at their rated capacity. Second, in actual practice on electric railroad work.

The contractor in making his guarantee will base it upon the constant load basis when the engine is delivering its full rated power, but he will also state what economy can be obtained from his engine when working on a variable load such as electric railroad work.

In case it is found impracticable by the engineer who conducts the test on the engines, to determine accurately the delivered power, it will be taken as 8 per cent. less than the indicated horse power of the engines as shown by indicator diagrams, on Tandem engines, and 11 per cent. on cross compound engines.

Specifications. The contractor should submit detail specifications with each proposition which shall state the class of material and workmanship that will enter into the construction of the engine which he proposes to furnish under these specifications.

Drawings. The contractor shall furnish to the consulting engineer of the purchaser complete set of blue prints within two weeks from the date of the awarding of the contract, of each engine, giving all necessary information regarding the engines, to enable him to properly lay out the foundations for same.

Inspection. All the machinery purchased under these specifications will be subject to the inspection and approval of the purchaser.

Payment. The above machinery will be paid for as follows:

One-quarter cash on arrival of the machinery at the power house side track at New Orleans; one-quarter cash on the successful starting of the engines, and the balance within 60 days from said date, provided the requirements have been ful-

filled and they have been accepted by the purchaser.

All engines furnished under these specifications shall be erected in complete working order on foundations furnished by the purchaser, on or before the first day of July, 1895, and it is understood that a forfeiture of $25 per day as liquidated damages shall be deducted from the contract price for each and every day after said date that the engines are unable to operate successfully, it being understood that the contractor is not to be delayed in erecting or starting the engines by the purchaser. B. J. A. **Time of Completion.**

**180. Specifications for Boilers.** The boilers called for under these specifications will be erected in complete working order on foundations furnished by the purchaser in the power station building located on a steam railroad side track in New Orleans, La. **In General.**

Propositions will be considered on the following sizes: **Sizes.**

*Proposition No. 1.* On three boilers capable of developing 250 horse power each on a basis of thirty pounds of water per horse power converted from 100 degrees Fahr. into steam at 70 pounds per square inch.

*Proposition No. 2.* On three 200 horse power boilers. Same rating and conversion.

All boilers furnished shall be of the horizontal water tube type. **Type**

The shells shall be of first quality of low carbon steel of Otis or Shoenberg manufacture, or other equally as good, having a tensile strength of about 60,000 pounds per square inch, and each sheet shall have the maker's name stamped where it will be plainly visible.

All tubes entering into the construction of the boilers shall be of first-class quality, and the bidder shall state what make of tubes he will use.

The successful bidder will be required to replace all tubes that burn out within 90 days from the date of the starting of the boiler, provided it is shown that the boilers were not forced beyond their capacity during the said 90 days.

Each boiler will be provided with one Ashcroft, Crosby or Schaffer & Budenberg nickel plated steam gauge or other equally as good, which shall have a dial not less than 12 inches in diameter.

One water column complete with three gauge cocks and glass water gauge.

The water column shall have a quick opening valve in each pipe leading to it so as to shut the steam or water off quickly in case of an accident.

Each boiler shall also be provided with an Ashcroft or other standard pop safety stop valve, and to be provided, if possible, with some form of strainer or purifier where the feed water enters the boilers.

Each set of boilers called for in the above propositions shall be furnished with one complete set of firing irons and flue blower or cleaner. Asbestos seated blow-off cocks and all other valves which usually accompany boilers, with the exception of steam and feed water connections, will be furnished by the contractor.

**Heating Surface.** All boilers shall be provided with at least 11½ square feet of heating surface per horse power.

**Settings.** In case the boilers are so designed as to be set in batteries of three, and be easily accessible for cleaning, they will be set in brick work close together with wall on the outside provided with air space and with fire brick walls between the boilers. In case, however, there are side doors on the boilers, the settings will be so arranged that two of the boilers will be set in one battery and the third one set by itself, but so provided that a fourth boiler can be added in the future without having to change the present setting.

All outside walls shall be of red pressed brick.

The boiler settings shall be lined throughout with good quality of fire brick extending the entire length of the boiler.

The bridge wall will also be lined with fire brick.

The contractor will state how much additional will be charged for each boiler in case a mechanical stoker or Hawley Down-Draft Furnace is adopted. He will name the make of stoker which he proposes to furnish.

The boilers shall be designed to carry a working pressure of 140 pounds and shall be tested to 250 hydrostatic pressure. Steam Pressure.

Each proposition will be accompanied by complete detail specifications giving the sizes of the principal parts of the boilers, the grate surface and the number of square feet of heating surface of each boiler. Specifications.

Specifications will also state the quality of material and workmanship that will be furnished and give a detail statement of the attachments that will go with each boiler.

The above boilers will be subject to the inspection and approval of the purchaser. Inspection.

All of the material called for will be erected in complete working order at New Orleans, La., on or before the first day of July, 1895. It is understood that a forfeiture of $25 per day as liquidated damages will be deducted from the contract price for each and every day after said date that the purchaser is unable to successfully operate his plant through the boilers not being ready to run, it being understood that the contractor will not be delayed by the purchaser. Time.

Payments to be made as follows: One-quarter cash on delivery of boilers at the power house of the purchaser; one-quarter upon the successful starting of the plant and the balance within 60 days from the date of successful starting, provided the boilers have been accepted by the purchaser. Payment.

B. J. A.

**181. Specifications for Condensers and Pumps.** All the machinery furnished under these specifications will be delivered F. O. B., cars at the power house of the railroad company in New Orleans, La., on or before the first day of June, 1895. In General.

Proposals will be received on the following sized condensers: Sizes.

*Proposal No. 1.* On one independent steam driven jet or surface condenser, which shall be capable of condensing the steam from 750 horse power of engines. Said engines to be compound and to receive steam at 125 pounds initial pressure on the high pressure cylinder, and consume

18 pounds of water per horse power per hour. The condenser to be capable of maintaining a vacuum of 27" for 18 hours continuously when working at the above capacity and receiving the circulating or injection water at a temperature of sixty degrees Fahr. with pumps running at a piston speed not exceeding sixty feet per minute.

*Proposal No. 2.* On three jet or surface condensers having a capacity of 250 horse power each, same design, conditions and guarantees as Proposal No. 1.

*Proposal No. 3.* On one 500 horse power jet or surface condenser and one 250 horse power jet or surface condenser, same guarantees, conditions, etc., as Proposal No. 1.

*Proposal No. 4.* On one jet or surface condenser having a capacity of 600 horse power. Same conditions and guarantees as Proposal No. 1.

*Proposal No. 5.* On one jet or surface condenser having a capacity of 400 horse power and one of 200 horse power. Same conditions and guarantees as Proposal No. 1.

*Proposal No. 6.* On three jet or surface condensers having a capacity of 200 horse power each. Same conditions and guarantees as Proposal No. 1.

**Pumps.** Propositions will also be received on the following sized Independent steam driven feed pumps.

On two outside packed, single acting, brass plunger boiler feed pumps having a capacity sufficient to deliver 20 gallons of water per minute when supplied with steam under 125 pounds pressure, and delivering water against the same pressure, and running at a piston speed not exceeding 60 feet per minute.

The contractor will also submit propositions on duplex pumps.

**Specifications** Each bidder will submit with his proposition complete specifications giving in detail the special construction of his machine and in case of surface condensers will state the number of square feet of cooling surface which will be furnished. He will also state the diameter and stroke of the

air and circulating pumps and steam cylinders. Brass or composition piston rods must be furnished for the steam and water ends of both the condensers and boiler feed pumps.

The above machinery will be subject to the inspection and approval of the purchaser or his duly authorized representative. B. J. A. **Inspection and Approval.**

**182. Specifications for Economizers.** The economizers furnished under these specifications will be erected in complete running order in brick work furnished by the contractor, on foundations furnished by the purchaser in the power house of the railroad company at New Orleans, La., on or before the first day of June, 1895. A side track from a steam railroad will extend to the power house. **In General.**

The economizer will be of 500 horse power and placed in a passage way leading from the boilers to the smokestack and will consist of vertical cast iron tubes, arranged in such a manner that their ends can be removed so as to make the interior of the tubes easily accessible for cleaning. Each tube shall have some form of mechanical scraper traveling the full length of the tube to remove soot, and the series of scrapers shall be operated by one electric motor or independent steam engine which shall be furnished by the contractor. **General Design**

The contractor shall give the length, outside and inside diameters, of the tubes and the number which he proposes to furnish. He will also give the method of casting the pipes, making of joints, and general specifications describing the machine. No tubes will be used which are not cast on end and made of thoroughly first-class quality of fine grey cast iron. **Tubes.**

He will state the number of valves and kind which he proposes to furnish with his economizer. Nothing but bronze seated gate valves shall be used in the steam or water pipes leading to and from the economizer. **Valves.**

The purchaser will furnish all pipe work leading to the outlet and inlet of the economizer, but the contractor will furnish all other valves and additional piping required. **Pipe Work.**

Guarantee. The contractor will state what fuel economy he will guarantee to save over an ordinary boiler setting which has no economizer, provided the temperature of the gases delivered to the economizer are as follows:

First. With gases at 450 degrees Fahr.

Second. With gases at 550 degrees Fahr.

Third. What temperature the economizer will deliver water to the boiler when receiving water at 110 degrees Fahr. with the gases entering the economizer at 450 degrees Fahr.

Fourth. With gases entering the economizer at 550 degrees Fahr.

Test. All tubes furnished shall be tested to an hydraulic pressure of 350 pounds per square inch before being shipped from the company's works, and after the economizer has been put in operation it will be tested by the purchaser's engineer to ascertain whether or not it complies with these specifications.

All material that proves defective within thirty days from the date of the successful starting of the machine, shall be replaced by the contractor without expense to the purchaser.

Suits. The contractor shall guarantee to protect the purchaser from suits for infringements of patents.

Inspection and Approval. All material furnished under these specifications shall be subject to the inspection and approval of the purchaser. B. J. A.

In General. **183. Specifications for Electric Generators.** The machines that will be purchased under these specifications will be erected in complete running order on foundations furnished by the purchaser, in the power house of the St. Charles Street Railroad Company, located on a side track of a steam railroad in New Orleans, La. The exact location of the power house not yet being determined it is impracticable to designate the road on which the track will be located.

Sizes. Propositions will be considered on each of the following sizes and types of generators:

*Proposition No. 1.* On three 200 kilowatts direct-connected multipolar railway generators, designed to give an electrical output of 400 amperes at 500 volts when running at a speed of 150 revolutions per minute.

These generators will operate at a potential varying from 500 to 550 volts, but the kilowatt rating shall be based on a potential of 500 volts.

Each generator shall be provided with suitable projecting lugs for attaching to the cast-iron base of the engine to which it will be direct-connected.

Means must be provided for slipping the field pieces off the armature side-wise, or by separating the fields in a vertical plane in halves and sliding them away from the armature, or by separating the fields on a horizontal plane so the top piece can be lifted off and suitable removable blocks put between the lower field piece and the engine bed or foundations so that by removing these blocks the field casting can be lowered sufficiently to allow the field coils to be slipped off.

No bearings will be furnished with the generator, as the armature will be carried directly on the engine shaft. The bore of the armature hub will be given by the purchaser. The generators, however, should have their own brush supporting devices which should be attached to the fields of the machine so as to make it unnecessary to attach the brush holder brackets to the engine castings. In case the latter is necessary, however, the expense for such attachment will be borne by the contractor.

*Proposition No. 2.* On three generators of the same design as called for in proposition No. 1, but to run at 250 revolutions per minute.

*Proposition No. 3.* On three 200 kilowatt generators of the same design as called for in Proposition No. 1, but to run at a speed of 100 revolutions per minute.

*Proposition No. 4.* On three 200 kilowatt generators to run at a speed of 80 revolutions per minute. Same design and conditions as Proposition No. 1.

*Proposition No. 5.* On three generators of the same design, but to have a capacity of 150 kilowatts, and to run at a speed of 150 revolutions per minute.

*Proposition No. 6.* On three generators of 150 kilowatt capacity each, to run at a speed of 250 revolutions per minute.

*Proposition No. 7.* On three 150 kilowatt generators similar to those called for under Proposition No. 1, but to run at 100 revolutions per minute.

*Proposition No. 8.* On three 150 kilowatt generators similar to those called for under Proposition No. 1, but to run at 80 revolutions per minute.

**Efficiency.** The contractor shall state in each proposition the efficiency his generators will give, and it must be in the form of a guarantee.

By efficiency is meant the result that is obtained by dividing the total energy in kilowatts delivered on the switchboard of the station by the mechanical horse power delivered to the armature of the generator, due allowance being made for the loss in the mains leading from the generator brushes to the switchboard. The power delivered to the armature shall be taken as the indicated horse power in the cylinders of the engine, as measured by the engine indicator, less the indicated power required to drive the engine and generator running light or with no load.

**Heating.** The generators shall be capable of giving their full capacity for a period of 18 hours in continuous operation without serious sparking at the brushes, and without raising the temperature of the armature or field coils more than 72 degrees Fahr. above the surrounding atmosphere.

**Regulation.** The machine shall be self-exciting and shall maintain a practically constant voltage with the load varying from half to full load when driven at a uniform speed. They shall be able to run in multiple with each other and divide the load proportionately among them without it being necessary for the attendant to adjust regulating devices.

**Station Equipment.** With each generator shall be furnished:

One main switch of suitable capacity for the machine.

One automatic circuit breaker.

One lightning arrester.

One Weston illuminated dial ammeter reading to 500.

One field rheostat.

One four point potential switch.

And with each complete proposition the following:

One Weston volt meter reading from 0 to 650 volts.

One Weston illuminated dial shunted station or bus ammeter reading to 2,000 amperes.

Seven feeder panels, each one to have the following instruments upon it:

One Maine switch to carry 250 amperes.

One Weston illuminated dial ammeter reading 250 amperes.

One automatic circuit breaker, suitable for panel, and such minor details as go to complete the system of the contractor.

All to be mounted upon marbleized slate panels of suitable size to build into a switchboard. No wood or other combustible material can be used in the construction of these instruments.

**Brushes.** Carbon brushes are preferred, and when carbon brushes are used brush holders shall be so designed as to clamp the carbon brush securely and have a practically solid connection to binding post from which the flexible cables lead to switchboard. The object being to prevent heating of the brushes and the electrical loss common to some machines faulty in this respect. Should the type of generator bid upon be such as to necessitate copper brushes the builder of said machine will state fully how such brushes are made and secured.

**Templates.** The contractor shall furnish the engine builder, free of cost to the purchaser, a template for each machine, giving the bore of the armature hub and key-seating for same.

**Expert.** The contractor shall furnish a thoroughly competent expert to superintend the erection of the generators, who shall remain in charge of the generators for thirty days after they have started. He shall give all necessary information to such men as may be designated by the purchaser, to enable them to properly operate the generators during the said thirty day period.

**Labor.** Contractor will furnish all necessary labor and material for erecting the generators complete

ready to operate, and for connecting the generators with the switchboard.

Inspection and Approval.

The above machinery will be subject to the inspection of the purchaser, who shall have the authority to decide whether or not the machinery conforms to these specifications.

Test.

An accurate test will be made when the generators are in proper condition to work and it is intended that the guarantee made by the contractor will be fulfilled.

Payments.

Payments will be made as follows: One-quarter cash on arrival of machinery at the power station site at New Orleans; one-quarter on the successful starting of the plant and the balance within sixty days thereafter, provided the generators have been approved and accepted by the purchaser. It is understood of course that the contractor will not be delayed in starting his machines by the purchaser.

Time.

The above material to be delivered in running order on or before the first day of July, 1895, and it is understood that the contractor will forfeit $25 per day as liquidated damages for each and every day after the above date that his work remains incomplete.

Specifications.

Each bidder will submit a detailed specification of the machines which he proposes to furnish. It is the intention of the writer of these specifications to draw them broad enough to permit any manufacturer of first-class machinery to bid upon the generators, but if any one is prohibited from bidding by any clause in the specifications, they may submit a proposition pointing out the prohibitive clause, and their bid, if the machinery is of first-class construction, will be considered. It is understood, however, that the speed here given can not be varied from to any great extent.

B. J. A.

In General

**184. Specifications for Electric Motors.** The motors that will be purchased under these specifications will be delivered by the contractor at the factory of the car builder, which will be located in the vicinity of Philadelphia, New York, Cleveland or St. Louis. The cars may be manufactured at some other point than the ones mentioned,

but the contractor will deliver the motors as above specified, provided the cars are built within one hundred miles of one of the above points.

Sizes. Propositions will be considered on the following:

*Proposition No. 1.* On 40-500 volt constant potential single reduction electric motors having a rated capacity of 25 horse power each, and capable of exerting a horizontal drawbar pull of 1,170 pounds, when running at a speed of eight miles per hour, or a drawbar pull of 625 pounds when running at a speed of fifteen miles per hour.

The average speed of the motors will be between eight and ten miles per hour and the maximum speed about fifteen miles per hour.

*Proposition No. 2.* On 40-500 volt constant potential single reduction electric motors having a rated capacity of 30 horse power each, and capable of exerting a horizontal drawbar pull of 1,400 pounds when running at a speed of eight miles per hour, or 750 pounds when running at a speed of fifteen miles per hour.

Current. The contractor shall state what current will be required by the motors at a potential of 500 volts when developing the power indicated above, on a straight, level and clean track.

Type of Motor. Each motor furnished shall be of the latest form and design of water-proof motor built by the manufacturer.

Gearing. All gearing used in connection with the motors and car axle shall be cut gears. The pinion on the armature to be made of steel and the gear attached to the car axle shall be made of such material as the contractor sees fit to recommend.

Auxiliaries. Each motor will be mounted upon a single car, making a total of forty cars to be equipped with one motor each, and with each motor shall be furnished a complete set of gears for attaching to the car axle. Two controlling stands with suitable rheostats, blow-out devices and other automatic attachments for successful working. One trolley with iron pole and bronze wheel with plumbago bearings. The trolley pole to be provided with suitable base and springs for attaching to the car top. One lightning arrester, one

fuse block, two overhead switches for making and breaking the circuit, and all necessary wiring in the car body, and underneath the seats to suitably connect the controller, rheostat and motor for successful operation, and such other special devices as may be necessary to conform to the standard system of the bidder.

Labor. The contractor will furnish all necessary labor to mount the motors on the car axles at the works of the car manufacturer. Do all the car wiring (except for lights) necessary to connect the motors to the controllers and rheostats and otherwise equip the car for successful operation.

Heating and Sparking. The motors shall be capable of performing the work required of them, as given in these specifications in ordinary service, for a period of 18 hours in continuous operation without raising the temperature of the armatures or the field coils to more than 75 degrees Fahr. above the surrounding atmosphere, and shall do their work without excessive sparking at the commutator brushes.

Mounting. The type of motor considered as standard in these specifications is a single reduction motor geared direct to the car axle, and when this class of motor is used it shall be suspended upon some flexible connection which will relieve the car axle of as much weight as possible, and the contractor will state in his proposition, so far as practical, the method or special design which he proposes to use in mounting the motors.

In case the manufacturer should furnish single motor geared to both axles under these specifications, the bidder shall state fully the method which will be used in mounting and supporting the motors.

Cars and Trucks. The car bodies and trucks will be furnished by the purchaser but the motors are expected to handle an 18 foot closed car body when fully loaded, and to pull the trailer when necessary on a level track around ordinary curves.

Speed of Armatures. The bidder will state the number of revolutions per minute that his armature will run when driving a car mounted on 33 in. wheel at a speed of eight miles per hour.

Wheels. The 33 in. wheels will be used throughout and

the motors and gearing are so proportioned as to exert their rated capacity with this diameter of wheel.

**Winding.** The contractor will state the diameter of the wire used in the armature and whether or not the armature is wound with one or more windings through each slot, and if two or more wires are used in such slot, whether or not they are connected in multiple on the commutator strips. He will also give the diameter of the wire used on the field coils.

**Delivery.** The contractor will deliver these motors to the car manufacturer within ninety days from the date of the awarding of the contract, and the motors will be shipped from the factory of the car builder to New Orleans by the car manufacturer, and hauled to the car barn or placed therein by the purchaser, where suitable pits will be provided for cleaning and repairing the motors.

When the contractor has received notice from the purchaser that he is ready to open the road for traffic he (the contractor) shall send a thoroughly competent expert or electrical engineer to New Orleans to superintend the starting and operation of the motors and give instructions to the employees of the railroad company for a period of thirty days which shall be known as the trial period. All expenses and salary of said expert to be borne by the contractor.

**Trial Period.** As soon as the road is ready for operation the purchaser will open it for traffic and operate the cars thereon for a period of thirty days to determine whether or not the motors will do the work required of them successfully and comply with these specifications. During this period the purchaser will furnish all necessary employees and power for operating the cars. Said employees to operate the motors in accordance with instructions of the contractor's expert. It being understood, however, that the motors must make the speed and do the work called for under these specifications during the said thirty days. All parts of the motors that burn out, break, or otherwise prove defective aside from ordinary wear and tear, during the said thirty days, shall be re-

placed by the contractor free of cost to the purchaser.

**Inspection and Approval.** The machinery purchased under these specifications will be subject to the inspection and approval of the purchaser.

**Specifications.** It is the intention of the writer of these specifications to have them sufficiently broad to allow all manufacturers of first-class machinery to bid under them and if anything in them seems to be prohibitive the bidder will submit his proposition pointing out wherein he can not conform to the specifications. He will also submit detailed specifications giving a list of material which he proposes to furnish. The intention of these specifications being only to definitely state the work that the motors will be required to do.

B. J. A.

**General Specification.** **185. Specifications for the Reconstruction of a Horse Railway Track to be Used as an Electric Railway in a City.** The work consists in removing the existing track of the . . . company in the city of . . . and replacing it with the track described in the following specifications. The track is . . . feet long and will contain . . . plain curves, . . . branches off curves, . . . electric railroad crossings and . . . steam railroad crossings. The contractor will also be required to lay the tracks in the car-shed and the special work connecting the car-shed tracks with the tracks in the street. He will also furnish and erect the poles, span wires, trolley wire and feeder wire as herein described.

All rails, stringers and ties taken out of the old track shall belong to the railroad company and shall be delivered by the contractor either at the railroad company's yards, or forwarded on board cars to the order of the railroad company as the engineer may elect.

All work not enumerated in these specifications necessary for the construction of a first-class track and line shall be performed by the contractor. All work shall be done under the supervision and to the satisfaction of the engineer of the railroad company, and instructions as to details given by the engineer or his representa-

tive shall be fully carried out. No bills for extra work will be paid except for extra work done by the written order of the engineer.

The contractor shall agree to protect the railroad company from the beginning of the construction until the road is accepted by the officers of the railroad company from all loss of material by theft and from all damage suits and claims arising from personal injuries or property losses sustained in the construction of the road. The contractor shall also agree to assume the liability in any suit for infringement of patent, arising out of the material used in the construction of the road or out of the use of any patented process.

The railroad company will secure the necessary permits from the municipality and will make the necessary crossing arrangements with the roads which it intersects. The contractor, however, must perform all work in accordance with city regulations, and shall carry out any instructions given by the city authorities.

Where it is not herein specified that the material manufactured by a certain company shall be furnished, the contractor shall name in his bid the manufacturer of the material which he proposes to furnish and wherever possible shall submit samples.

The following drawings may be seen at the office of the engineer. (1) General map of route, showing location of track and proposed location of poles. (2) Detail drawings of crossings, special work and car-shed tracks. (3) Drawing showing the length, route and tapping-in points of feeders.

**Material**

The rails shall be standard girder rails, seven inches in height, weighing not less than eighty pounds per yard. These rails shall be delivered in lengths of not less than fifty-five feet. The ties shall be of white oak, sawed six by eight inches in section and eight feet long. Brace tie-plates, fitting and supporting the head of the rail, shall be used. The joints shall be cast-welded, but the contractor shall supply enough fish plates for use on the rails temporarily as herein described. The trolley wire shall be No. 00 hard

drawn copper and the span wire No. 4 soft iron wire covered with weatherproof insulation. The guy wire shall be No. 6 iron wire covered with the same insulation. The span wire shall have a tensile strength of 2,500 pounds and the guy wire a tensile strength of 1,800 pounds.

The poles shall be thirty feet long and shall be made of steel tubing. Those which are used to support curves and terminals shall be made of eight inch, seven inch and six inch pipe and shall weigh not less than eight hundred pounds. Poles used only for supporting span wires shall be made of six inch, five inch and four inch pipe and shall not weigh less than five hundred pounds. Poles which carry feed wires shall be made of seven inch, six inch and five inch pipe and shall weigh not less than six hundred and fifty pounds. All poles shall be provided with caps and rings to cover the joints.

All of the material used in the construction of the road not herein enumerated shall be of standard design and subject to the approval of the engineer.

**Road-bed.** For double track an excavation 18 feet wide and 18 inches deep shall be made, and for single track an excavation 9 feet wide and 18 inches deep. Into this shall be placed 4 inches of crushed rock or gravel and rolled until solid. Clean rock which has been excavated from the street may be used for this purpose.

**Ties.** The ties shall be spaced 24 inches between centers. A tie shall be placed underneath each joint.

**Track-work.** The rails shall be laid 4 feet and 10 inches between gauge lines. Where there is double track, the distance between the gauge lines of the inside rails shall be 5 feet and 4 inches. Brace tie plates shall be placed under the rail at each tie and care taken that the brace is firmly against the rail before spiking. The ties shall be securely tamped with crushed rock or gravel until the top of the rail is at the established grade of the street and the track carefully lined and surfaced. Both rails shall be laid level by means of a straight-edge and a level. For lining and surfacing, the rails shall be temporarily connected by fish plates.

**Joints.** The cast-welded joint shall be used. The joint shall be 14 inches long and the casting shall weigh not less than 120 pounds. The iron used for this purpose shall be soft, grey pig. No scrap shall be used. Immediately before casting the joints, the rail-ends, 7 inches back of the joint, shall be thoroughly cleaned by emery wheels, sand blast or some other mechanical process. Care must be taken that the rail ends are in contact and perfectly in line before the joint is cast. Means must be provided for holding the rail in position while the joint is cooling. If there are slight irregularities in the rail surface after the joint is cast, they may be removed by filing the top of the rail, but the engineer shall have the right to reject any joint which is not in line or which is higher or lower than the rail. Joints so rejected shall be removed by sawing the rail 4 feet on each side of the defective joint. A piece of new rail 8 feet long shall be inserted in this opening and new joints cast on each end of it as described above. The contractor shall guarantee all cast-welded joints for one year and shall repair, free of charge, any which break in this time. In repairing broken joints, if the opening does not exceed 1 inch, the old joints may be chipped off, a section of rail fitting the opening inserted, and a new joint cast around it, the same precautions as to cleaning and preparing the joint being followed as outlined above. If the opening exceeds 1 inch, the joint must be cut out, a piece of rail 8 feet long inserted and new joints cast upon each end of it.

All joints shall be cast-welded except those in the special work and crossings, and those joints connecting the special work and crossings with the straight track. These joints shall be supplied with six-hole fish plates fitting the section of rail which is used.

**Special Work.** The special work shall be made of a section of rail which will connect with the rail used on the straight track without the use of combination fish plates. Easement curves as indicated on the drawings shall be used at the ends of all curves where the radius is less than 150 feet. Curves of

less radius than 150 feet shall have both rails grooved; those varying in radii from 150 to 400 feet shall have the inside rail grooved; and those of greater radii than 400 feet may be sprung from the rail used on the straight track. Switches, mates, frogs and crossings shall be provided with hardened steel plates set into the castings to take the wear. The special work shall be laid according to the measurements given on the drawings and shall be made to line in neatly with the straight track. Wherever necessary the contractor shall furnish special ties, long enough to support the special work. In laying special work, the directions as given above shall be carried out, except that in laying curves of less than 150 feet radius, the outside rail shall be laid ½ inch higher than the inside rail.

Bonds. The contractor will not be required to bond the cast-welded joints. All joints not cast-welded shall be bonded with a four naught bond of the . . . type. At crossings and special work, each straight rail shall be connected to the corresponding straight rail on the other side by means of an insulated copper cable of 500,000 c. m. cross-section. The connection between the cable and the rail shall be made by means of a copper terminal, shown on the feeder drawing. The place on the rail where this terminal connects shall be amalgamated and the surface of the terminal shall be amalgamated and coated with an amalgam.

Paving. The paving shall follow the welding of the joints as closely as possible. The road-bed up to the tops of the ties shall be filled with crushed macadam, rammed in place. The space between the tracks of a double track shall be paved with the same material as the street outside the tracks. The space between the rails of the track shall be paved with granite blocks, six inches deep, laid on a bed of sand. The space outside of the rails shall be paved with the same material as the rest of the street. In all cases the city regulations in regard to street paving shall be fully carried out and the work shall be done to the satisfaction of the city authorities. Paving which has been removed for the reconstruction of the track may be replaced by the contractor, if approved by the

engineer. All old paving material not used shall belong to the contractor and shall be removed by him. Immediately after the paving is finished the contractor shall remove all dirt from the street and leave it in a neat condition.

**Street to be Kept Open.** During the building of the road the contractor shall, at his own expense, put in temporary wagon crossings made of ties whenever required by the city authorities. He shall, as far as possible, keep the street open for traffic and shall supply the necessary signal lamps and watchmen.

OVERHEAD CONSTRUCTION.

**Poles.** Poles supporting the straight line shall be set in a hole 6 feet 6 inches deep and 18 inches in diameter. Poles supporting curves shall be set in a hole 6 feet 6 inches deep and 24 inches in diameter. The space around the poles shall be filled with concrete, composed of 1 part of cement, 2 parts of sand, and 4 parts of crushed rock. In setting poles, the top of the pole shall be given a rake of 8 inches from the vertical. City regulations in regard to setting poles shall be strictly complied with. The sidewalk at the base of the pole must be restored to its original condition. Before erection, poles and cross-arms shall receive one coat of asphalt paint and after erection shall receive another.

**Line Work.** The trolley wire shall be placed as nearly as possible over the center of the track and shall not be less than 18 or more than 20 feet above the rail. The trolley wire shall be anchored at all curves and crossings. The hangers, strain insulators, feeder yokes and all other overhead appliances shall be of the manufacture of . . The connection between the span wire and the pole shall be through a strain insulator. Strain insulators shall be placed in all guy wires and pull-off wires. All joints in the trolley wire shall be made at suspensions by means of splicing ears. No splicing sleeves shall be used.

**Curves.** The trolley wire over curves must be so located that the trolley wheel rounds the curve without leaving the wire. Pull-offs must be located as designated by the engineer. Where necessary,

the contractor shall furnish switches and crossings to be located in the trolley wire at turn-outs.

Crossings. At crossings with other roads, where their consent can be obtained, live crossings will be installed, and cut-outs placed in the trolley wire. Where this consent can not be obtained, the contractor will install insulated crossings of a design to be approved by the engineer.

Lightning Arresters. Lightning arresters shall be located along the track, two to each mile. They shall be of the manufacture of . . . and the engineer shall designate their exact location and the manner in which they shall be connected with the trolley and feeder wires, and the manner in which they shall be grounded.

Section Insulators. Section insulators of the manufacture of . . . shall be placed in the trolley wire in the positions shown on the map of the route of the road.

Feeders. Feeders shall be furnished according to the drawing. The cross-arms shall be of iron and of an ornamental design. They shall receive one coat of paint before erection and another after erection. The pins for the straight line shall be of locust, and those supporting feed wire on curves shall be made of steel. The insulators shall have recesses in the top for the support of the feed wire and shall be of the manufacture of . . . Feed wires shall be pulled up neatly and shall be protected from abrasion by trees or other poles. Each feeder shall be drawn into the power house and left long enough to connect with its proper switch on the feeder board. The contractor, however, will not be required to make this connection. The contractor shall also furnish and install the cables for ground feeders, in the location shown on the feeder drawing. The connection between the ground feeder and the rail shall be made by means of a brass terminal, the dimensions of which are shown on the feeder drawing. The surface of the brass terminal shall be amalgamated and the terminal shall be bolted to an amalgamated area on the rail. The contractor shall leave the ends of ground feeders long enough to connect with the switchboard, but he will not be required to make this connec-

tion. The feeder line shall be guyed where necessary as the engineer may direct. R. McC.

General Specifications.

**186. General Specifications for the Track and Overhead Constuction for an Electric Railway in a Country Town.** This work consists of the laying of . . . feet of single track, containing . . . curves . . . terminals and . . . diamond turn-outs in the city of . . . It also includes the laying of the tracks and special work in the car-shed and the erection of the poles, span wires, trolley wires and feeders.

All work shall be done under the supervision and to the satisfaction of the engineer of the railroad company. Instructions as to details given by the engineer or his representative shall be fully carried out. No bills for extra work will be allowed except for extra work done by the written order of the engineer.

All work not mentioned in these specifications necessary for the construction of a first-class road shall be performed by the contractor. He will not be required to work on rainy days, but it is expected that he will push the work to its earliest possible completion.

The contractor shall agree to protect the railroad company from the beginning of the construction until the road is accepted by the officers of the railroad company, from all loss of material by theft, and from all damage suits and claims arising from personal injuries or property losses sustained in the construction of the road.

In making his bid, the contractor shall name the manufacturer of the material which he proposes using and wherever possible shall furnish samples.

The following drawings may be seen at the office of the engineer. (1) General map of route, showing location of track, and proposed location of poles. (2) Profile, showing the necessary grading. (3) Detailed drawings of special work and car-shed tracks. (4) Drawing showing the location and sizes of the feeders.

Material.

The rails shall be Tee rails, weighing sixty pounds per yard, of the American Society of Civil Engineers' standard section. The ties shall be of

white oak, sawed, 6 by 8 inches in section and 8 feet long. Four-hole angle bars fitting this section of rail are to be used at rail joints. The trolley is to be No. O, hard drawn copper, and the span wire 9-32" galvanized iron cable. The poles are to be of white cedar, neatly trimmed and straight. Those for straight line work shall be 30 feet long with 6 inch tops, and those supporting curves or terminals shall be 30 feet long with 8 inch tops. All other material used in this work shall be of standard design, and shall be subject to the approval of the engineer.

**Grading.** Within the city limits, the top of the rail shall conform to the established grade of the street. Outside of the city limits, the grade shown on the profile will be followed. Where necessary, grade stakes to guide the contractor will be set by the engineer. Where the track is either above or below the surface of the roadway, the roadway for 4 feet outside the rails shall be graded to slope to the ends of the ties.

**Road bed.** For the roadbed, an excavation 9 feet wide and 16 inches deep shall be made. Into this shall be placed 3 inches of crushed rock or gravel and rolled with a heavy roller until solid. In macadam streets, the stone which is taken from the street may be used for this purpose. Where there is a surplus of stone in the street, it shall be moved forward to such point as needed. All surplus dirt shall be hauled away by the contractor and the street left in a neat condition. After completing the track the roadbed shall be filled with broken stone or gravel to the top of the rail. The material used for this purpose shall be clean and free from dirt.

**Ties.** The ties shall be spaced 39 inches between centers, except at the joints, where a tie shall be placed directly under the joint, with another tie on each side of it, 8 inches from it.

**Track Work.** The rails shall be laid 4 feet, 8½ inches between gauge lines, and at turn-outs where there is a double track, the distance between the gauge lines of the inside rails shall be 6 feet. The rails shall be fastened to the ties by two hook head spikes at each point where a rail crosses a tie. The center of the track shall correspond with the

center of the street unless otherwise directed. The ties shall be securely tamped until the rail is at the proper grade, and the track shall be carefully lined and surfaced. Both rails shall be laid level by means of a straight edge and a level.

Joints. Wherever possible, joints shall be placed opposite one another. The angle-bars shall first be placed on the joints so that the track may be tamped, lined and surfaced. After this is completed, the angle-bars shall be removed and the bonds placed in position. All lining and surfacing must be done before the bonds are inserted. After all the bolts in the angle-bars are drawn up as tightly as possible, one man shall strike the head of the bolt with a hammer, while another draws up on the nut with a wrench. This operation shall be repeated with each bolt until the nut can not be turned. The tightening of these bolts shall be the last operation before the track is filled in.

Special Work. Special work shall be laid according to the measurements given on the drawings and must be made to line in neatly with the straight track. At turn-outs, the contractor shall furnish special ties, long enough to support the switches, mates, frogs and curved rails. In laying special work, the directions as already given shall be followed, except that in laying curves, the outside rail shall be laid ¾ inch higher than the inside rail.

Bonds. Each joint shall be bonded with a four-naught stranded bond placed beneath the joint plate. The bonds shall be of the . . . or . . . type. The two rails of the track shall be crossbonded every 300 feet by four-naught bonds of the same type. At turn-outs, the 4 rails shall be cross-bonded twice. If the holes for the bonds are punched at the rail mill, they must be reamed out before the bonds are inserted.

Cross-walks. All cross-walks torn up in the construction of the road shall be replaced by the contractor as soon as the track is filled.

Temporary Crossings. During the building of the road, the contractor shall at his own expense put in temporary wagon crossings made of ties whenever required by the city authorities. He shall also as far as possible keep the street open for traffic.

### OVERHEAD CONSTRUCTION.

Poles.

All poles shall be set 6 feet in the ground. Those which support curves or terminals shall be set in concrete. In straight line work, the poles shall be spaced not more than 115 feet apart.

Suspensions.

The trolley wire shall be placed as nearly as possible over the center line of the track. The distance from the rail to the trolley wire shall not be less than 18 feet nor more than 20 feet. The trolley wire shall be anchored at all curves and at all crossings. The connection between the span wire and the trolley wire shall be by means of a hanger of standard design to be approved by the engineer, and the connection between the hanger and the trolley wire shall be by means of a soldered ear, 15 inches long. All joints in the trolley wire shall be made at suspensions by means of splicing ears. No splicing sleeves shall be used.

Curves.

The trolley wire over curves must be so located that the trolley wheel rounds the curve without leaving the wire. Pull-offs must be located not further apart than 4 feet. Where necessary, the contractor shall furnish crossings and switches to be located in the trolley wire at turn-outs.

Lightning Arresters.

Lightning arresters shall be located along the track not more than 3,000 feet apart. They shall be of a design to be approved by the engineer, who shall designate their exact location and the manner in which they shall be connected to the feeders and trolley wire. They shall be grounded by means of a No. 6 insulated copper wire, soldered to a copper plate not less than one square foot in area, buried in a bed of wet, crushed charcoal, at least 6 feet deep in the ground.

Feeders.

Feeders shall be furnished according to the drawings above enumerated. They shall be drawn into the power house and their ends left long enough to connect with the switchboard. The contractor, however, will not be required to make this connection. The contractor will be required to furnish the ground feeders for connecting the rails with the switchboard. He will make the connection with the rails as indicated in the feeder drawing and will leave the ends of these feeders long enough to connect with the switchboard.

R. McC.

**187. General Specifications for Steel Highway Bridges and Viaducts.**[1] The following specifications have been adopted for highway bridges and viaducts by the American Bridge Company, they having been drawn by Vice-President C. C. Schneider, member American Society Civil Engineers. They will give structures from 20 to 25 per cent. heavier than those heretofore commonly erected for such purposes. The requirements provide for a most excellent shop practice without greatly increasing the cost, provided the shop is properly equipped with modern machine tools. It will be noted that a class of structures is provided for which is intended to cover all ordinary demands. The tables given at the end of this specification will be found especially valuable in preparing designs.

## GENERAL DESCRIPTION.

1. Bridges under these specifications are divided into six classes, viz: Classification.

Class A.—For city traffic.
Class B.—For suburban or interurban traffic with heavy electric cars.
Class C.—For country roads with light electric cars or heavy highway traffic.
Class D.—For country roads with ordinary highway traffic.
Class E1.—For heavy electric street railways only.
Class E2.—For light electric street railways only.

2. All structures to be of rolled steel, except the flooring and wheel-guards of Classes A, B, C, E1 and E2, and the stringers, flooring and wheel-guards of Class D, which may be of timber. Cast iron or cast steel will be permitted only in machinery of movable bridges and in special cases for shoes and bearings. Material.

3. The following types of bridges are recommended: Type of Bridges.

For spans up to 25 feet.—Rolled beams.
For spans from 25 to 40 feet.—Rolled beams or plate girders.
For spans from 40 to 80 feet.—Plate or lattice girders.
For spans from 80 to 140 feet.—Lattice girders.

[1] For specification for Steel Railroad Bridges, see Art. 185, p 459.

For spans over 140 feet.—Lattice girders or pin connected trusses.

Clearance

4. At an elevation of one foot and over above the roadway, the clear distance between trusses shall be at least 14 inches greater than the width of the roadway between wheel-guards.

5. For Classes A, B, C, E1 and E2 the clear headroom for a width of 6 feet over each track shall not be less than 15 feet, for Class D not less than 12½ feet, above the floor.

6. For bridges carrying electric cars the clear width from the centre of track shall not be less than 6½ feet at a height exceeding 1 foot 6 inches above the top of rails where the tracks are straight.

7. In determining the clearance on curves the extreme length of electric car shall be taken as 45 feet, the width 8 feet, and the distance between centers of trucks as 20 feet, unless otherwise specified.

Spacing of Trusses

8. The width between centers of trusses shall in no case be less than one-twentieth of the span between centres of end pins or shoes.

Handrailing.

9. A strong and suitable handrailing shall be placed at each side of the bridge, except where plate girders serve the same purpose, and be rigidly attached to the superstructure.

Nameplate.

10. Each bridge shall have such name plates suitably inscribed and located, as may be required.

Floor Beams.

11. All floor beams in through bridges shall be riveted to the main girders.

Stringers.

12. Steel stringers shall preferably be riveted to the web of the floor beams.

Wooden joists shall not be less than 3 inches thick, shall be spaced not more than 2½ feet between centres, and shall be dapped over the seat angles or floor beams to exact level. In the latter case they shall lap by each other over the full width of the floor beam, and shall be separated ½ inch for free circulation of air.

Roadway Planks.

13. For single thickness the roadway planks shall not be less than 3 inches thick, nor less than one-twelfth of the distance between stringers, and shall be laid transversely with ½ inch openings.

14. When an additional wearing surface is specified for the roadway, it shall be 1½ inches thick, and the lower planks, of a minimum thickness of 2½ inches, shall be laid diagonally and with ½ inch openings.

15. Wheel-guards of a cross-section not less than 6 inches by 4 inches on each side of the roadway shall be provided. They shall be blocked up from the floor plank with blocks 2 inches by 6 inches by 12 inches long, not over 5 feet apart centre to centre, held in place by one $\frac{3}{4}$ inch bolt passing through the centre of each blocking piece and securely fastened to the stringer below. The wheel-guards shall be spliced with half and half joints with 6 inches lap over a blocking piece. **Wheel-guards.**

16. The footwalk planks shall not be less than 2 inches thick nor more than 6 inches wide, spaced with $\frac{1}{2}$ inch openings. **Footwalk Planks.**

17. All plank shall be laid with the heart side down; shall have full and even bearing on and be firmly attached to the stringers.

18. For bridges of Classes A and B a solid floor, consisting of stone, asphalt, etc., on a concrete bed, is recommended. For this case the flooring will consist of buckle-plates or corrugated sections, and the concrete bed shall be at least 3 inches thick for the roadway, and 2 inches thick for the footwalk, over the highest point to be covered, not counting rivet or boltheads. **Solid Floor.**

19. Buckleplates shall not be less than 5-16 inch thick for the roadway and $\frac{1}{4}$ inch thick for the footwalk. **Buckle Plates.**

20. For solid floor the curb holding the paving and acting as a wheel-guard on each side of the roadway shall be of stone or steel projecting about 6 inches above the finished paving at the gutter. The curb shall be so arranged that it can be removed and replaced when worn or injured. There shall also be a metal edging strip on each side of the footwalks to protect and hold the paving in place. **Curbs.**

21. Provision shall be made for drainage clear of all parts of the metal work. **Drainage.**

22. The floor of bridges of Classes E1 and E2 shall consist of cross-ties not less than 6 inches by 6 inches, spaced with openings not exceeding 6 inches and securely fastened to the stringers by bolts. There shall be guard timbers not less than 6 inches by 6 inches on each side of each track, with their inner faces not less than 9 inches from centre of rail. They shall be notched 1 inch over every tie, and fastened to every fourth tie. **Floor of Class E1 and E2.**

## LOADS.

**Dead Load.** 23. In determining the weight of the structure for the purpose of calculating strains, the weight of timber shall be assumed at 4 pounds per foot B. M., the weight of concrete and asphaltum at 130 pounds, of paving brick at 150 pounds and of granite stone at 160 pounds per cubic foot.

The rails, fastenings, splices and guard timbers of street railway tracks, resting on cross-ties, shall be assumed as weighing 100 pounds per lineal foot of track.

**Live Load.** 24. The bridges of the different classes shall be designed to carry, in addition to their own weight and that of the floor, a moving load, either uniform or concentrated, or both, as specified below, placed so as to give the greatest strain in each part of the structure.

### CLASS A.—*City Bridges.*

For the floor and its supports, on each street car track or on any part of the roadway, a concentrated load of 24 tons on two axles 10 feet centres and 5 feet gauge (assumed to occupy a width of 12 feet), and upon the remaining portion of the floor, including foot walks, a load of 100 pounds per square foot.

For the trusses, for spans up to 100 feet, 1,800 pounds per lineal foot of each car track (assumed to occupy 12 feet in width), and 100 pounds per square foot for the remaining floor surface; for spans of 200 feet and over, 1,200 pounds for each lineal foot of track and 80 pounds per square foot of floor; proportionally for intermediate spans. (See table I.)

### CLASS B.—*Suburban or Interurban Bridges.*

For the floor and its supports, on any part of the roadway, a concentrated load of 12 tons on two axles 10 feet centres and 5 feet gauge (assumed to occupy a width of 12 feet), or on each street car track a concentrated load of 24 tons on two axles 10 feet centres; and upon the remaining portion of the floor, including footwalks, a load of 100 pounds per square foot.

For the trusses, for spans up to 100 feet, 1,800 pounds per lineal foot of each car track and 80

pounds per square foot for the remaining floor surface; for spans of 200 feet and over 1,200 pounds for each lineal foot of track and 60 pounds per square foot of floor; proportionally for intermediate spans. (See table I.)

CLASS C.—*Heavy Country Highway Bridges.*

For the floor and its supports, on any part of the roadway, a concentrated load of 12 tons on two axles 10 feet centres and 5 feet gauge (assumed to occupy a width of 12 feet), or on each street car track a concentrated load of 18 tons on two axles 10 feet centres; and upon the remaining portion of the floor, including footwalks, a load of 100 pounds per square foot.

For the trusses, same as for Class B, except load on car tracks for spans up to 100 feet will be 1,200 pounds and for spans of 200 feet and over, 1,000 pounds. (See table I.)

CLASS D.—*Ordinary Country Highway Bridges.*

For the floor and its supports, a load of 80 pounds per square foot of total floor surface or 6 tons on two axles 10 feet centres and 5 feet gauge.

For the trusses, a load of 80 pounds per square foot of total floor surface for spans up to 75 feet; and 55 pounds for spans of 200 feet and over; proportionally for intermediate spans. (See table I.)

CLASS E1.—*Bridges for Heavy Electric Street Railways only.*

For the floor and its supports, on each track a load of 24 tons on two axles 10 feet centres.

For the trusses, a load of 1,800 pounds per lineal foot of each car track for spans up to 100 feet; and a load of 1,200 pounds for spans of 200 feet and over; proportionally for intermediate spans. (See table I.)

CLASS E2.—*Bridges for Light Electric Street Railways only.*

For the floor and its supports, on each track a load of 18 tons on two axles 10 feet centres.

For the trusses, a load of 1,200 pounds per lineal foot of each car track for spans up to 100 feet; and

a load of 1,000 pounds for spans of 200 feet and over; proportionally for intermediate spans. (See table I.)

Impact. 25. To compensate for the effect of impact and vibration, 25 per cent. of the maximum strains resulting from the above mentioned live load shall be added thereto.

Wind Pressure. 26. The wind pressure shall be assumed acting in either direction horizontally:

*First.* At 30 pounds per square foot on the exposed surface of all trusses and the floor as seen in elevation, in addition to a horizontal live load of 150 pounds per lineal foot of the span moving across the bridge.

*Second.* At 50 pounds per square foot on the exposed surface of all trusses and the floor system. The greatest result shall be assumed in proportioning the parts.

Momentum of Street Cars. 27. For longitudinal bracing of structures carrying street railroads, the momentum produced by suddenly stopping the train shall be considered; the coefficient of friction of wheels sliding upon the rails being assumed as 0.2.

Centrifugal Force. 28. When the structure carrying a street railroad is on a curve, the additional effects due to the centrifugal force shall be considered.

## PROPORTION OF PARTS.

Least Thickness of Materials. 29. No material shall be used less than ¼ of an inch thick, except for lining or filling vacant places.

Permissible Tensile Strains. 30. All parts of the structure shall be so proportioned that the sum of the maximum loads, together with the impact, shall not cause the tensile strain to exceed:

On soft steel 15,000 pounds per square inch.

On medium steel 17,000 pounds per square inch.

31. The same limiting unit strains shall also be used for members strained by wind pressure, centrifugal force, or momentum of train, if any.

Net Sections. 32. Net sections must be used in all cases in calculating tension members, and, in deducting rivet-holes, they must be taken ⅛ of an inch larger than the size of the rivets.

33. Pin connected riveted tension members shall have a net section through the pin hole 25 per

cent. in excess of the net section of the body of the member. The net section back of the pin hole shall be at least 0.75 of the net section through the pin hole.

34. For compression members, these permissible strains of 15,000 and 17,000 pounds per square inch shall be reduced in proportion to the ratio of the length to the least radius of gyration of the section by the following formulæ: **Permissible Compressive Strains.**

For soft steel, $$p = \frac{15,000}{1 + \frac{l^2}{13,500r^2}}$$

For medium steel, $$p = \frac{17,000}{1 + \frac{l^2}{11,000r^2}}$$

where p = permissible working strain per square inch in compression.

l = length of pieces in inches, centre to center of connection.

r = least radius of gyration of the section in inches. (See table V.)

35. No compression member, however, shall have a length exceeding 120 times its least radius of gyration, excepting those for wind bracing, which may have a length not exceeding 140 times the least radius of gyration.

36. The reversal of strain in members of bridges of Classes A, B, C and D need not to be considered, but the members shall be proportioned for the strain giving the larger section. **Reversal of Strains.**

For bridges of Classes E1 and E2 members subject to alternate strains of tension and compression in immediate succession (as counter-stresses in web members or chords in continuous trusses) shall be so proportioned that the total sectional area is equal to the sum of areas required for each strain.

37. In case the maximum strains due to wind, added to the maximum strains due to vertical loading (including impact), shall exceed the following limits: **Combined Strains.**

On soft steel, 19,000 pounds per square inch.

On medium steel, 21,000 pounds per square inch, properly reduced for compression, addition must be made to such sections until these limits are not exceeded.

The permissible strains for the connections shall be increased proportionately.

38. Should the strains be reversed in any possible case, proper provision must be made for such strains in the opposite direction.

**Transverse Loading of Tension or Compression Members.**

39. When the floor system rests directly on the top or bottom chord, the latter must be so proportioned that the algebraic sum of the strains per square inch on the outer fibre, resulting from the direct compression or tension, and three fourths of the maximum bending moment (the chord being considered as a beam of one panel length, supported at the ends), shall not exceed the before-mentioned limiting strains in tension or compression, the proper amount of impact being added to each kind of loading.

40. The bending moment at panel points shall be assumed equal to that in the centre, but in opposite direction.

41. All other members which are subject to direct strain in addition to bending moment are to be similarly calculated.

**Shearing and Bearing Strains.**

42. The shearing strain on rivets, bolts or pins, per square inch of section, shall not exceed 11,000 pounds for soft steel, and 12,000 pounds for medium steel; and the pressure upon the bearing surface of the projected semi-intrados (diameter x thickness) of the rivet, bolt or pin hole, shall not exceed 22,000 pounds per square inch for soft steel, and 24,000 pounds for medium steel. (See table VII.)

**Field Connections.**

43. In field connections the number of rivets or bolts thus found shall be increased 25 per cent. if driven by hand, but 10 per cent. for rivets driven by power.

**Bending Strains on Pins.**

44. The bending strain on the extreme fibre of pins shall not exceed 22,000 pounds per square inch for soft steel, and 25,000 per square inch for medium steel, when centres of bearings of the strained members are taken as the points of application of the strains. (See table VI.)

**Plate Girders.**

45. Plate girders shall be proportioned on the assumption that $\frac{1}{8}$ of the gross area of the web is available as flange area. The compressed flange shall have the same sectional area as the tension flange; but the unsupported length of flange shall not exceed 20 times its width.

46. In calculating shearing strains and bearing strains on web rivets of plate girders, the whole of

the shear acting on the side next the abutment is to be considered as being transferred into the flange angles in a distance equal to the depth of the girder.

47. The shearing strain in web plates shall not exceed 9,000 pounds per square inch for soft steel, and 10,000 pounds per square inch for medium steel.

48. The web shall have stiffeners riveted on both sides, with a close bearing against upper and lower flange angles at the ends and inner edges of bearing plates, and at all points of local and concentrated loads, and also, when the thickness of the web is less than 1-60 of the unsupported distance between flange angles, at points throughout the length of the girder, generally not farther apart than the depth of the full web plate, with a maximum limit of 5 feet.

Rolled Beams.

49. The depth of rolled beams shall in no case be less than 1-30 of the span.

Floor Timber.

50. The fibre strain on floor timber from dead and live load without impact shall not exceed 1,200 pounds per square inch on yellow pine and white oak, and 1,000 pounds per square inch on white pine and spruce.

Provisions for Future Increase of Live Load of Classes E1 and E2.

51. Wherever the live and dead load strains of bridges of classes E1 and E2 are of opposite character, only 70 per cent. of the dead load strain shall be considered as effective in counteracting the live load strain.

## DETAILS OF CONSTRUCTION.

Camber

52. All truss bridges shall be given a proper camber.

Symmetrical Sections

53. All sections shall preferably be made symmetrical, and the pins placed in the line of the neutral axis.

Adjustable Members.

54. Adjustable members in any parts of structures shall preferably be avoided.

Truss Bridges.

55. All through spans shall have stiff end vertical suspenders.

Eye Bar Heads.

56. The heads of eye-bars shall not be less in strength than the body of the bar.

Nuts.

57. All nuts must be of hexagonal shape.

Lateral and Sway Bracing.

58. All lateral and sway bracing shall preferably be made of shapes which can resist compression as well as tension.

**Portals.** 59. All through spans with top lateral bracing shall have portals at each end of span, connected rigidly to endposts. They shall be as deep as the specified head room will allow, and provision shall be made in the end posts for the bending strain produced by the wind pressure.

**Diagonal Bracing.** 60. Deck bridges shall have diagonal braces at each panel, of sufficient strength to carry half the maximum strain increment due to wind and centrifugal force, if any.

**Gusset Plates.** 61. Pony trusses and through plate girders shall be stayed by knee braces or gusset plates at the ends, and at each floor beam or transverse strut.

**Temperature.** 62. Provision shall be made for a free expansion and contraction of all parts, corresponding to a variation of 150 degrees Fahrenheit in temperature.

**Bolsters and Expansion Rollers.** 63. All bridges exceeding 100 feet in length shall have hinge bolsters on both ends and at one end nests of turned friction rollers, running between planed surfaces. Rollers will not be less than 3 inches in diameter; and the pressure per lineal inch of roller, including impact, shall not exceed $1200\sqrt{d}$ for steel rollers between steel surfaces ($d$=diameter of roller in inches).

**Friction Plates.** 64. For bridges less than 100 feet in length, one end shall be free to move upon smooth surfaces.

**Bed Plates.** 65. Bed plates shall be so proportioned that the pressure upon masonry (including impact) will not exceed 400 pounds per square inch.

**Spacing of Rivets.** 66. The pitch of rivets, in the direction of the strain shall never exceed 6 inches, nor 16 times the thickness of the thinnest outside plate connected, and not more than 50 times that thickness at right angles to the strain.

67. At the ends of compression members the pitch shall not exceed four diameters of the rivet, for a length equal to twice the width of the member.

68. The distance from the edge of any piece to the centre of a rivet-hole must not be less than $1\frac{1}{2}$ times the diameter of the rivet, nor exceed 8 times the thickness of the plate; and the distance between centres of rivet-holes shall not be less than 3 diameters of the rivet.

**Splices.** 69. The butt joints of compression members shall be connected by splices to hold them truly in

position; all other joints in riveted work, whether in tension or compression, must be fully spliced.

70. All segments of compression members connected by latticing only, shall have tie plates placed as near the ends as practicable. They shall have a length of not less than the greatest depth or width of the member, and a thickness not less than 1-50 of the distance between the rivets connecting them to the compressed members. **Tie Plates.**

71. Single lattice bars shall have a thickness of not less than 1-40, and double bars connected by a rivet at the intersection of not less than 1-60 of the distance between the rivets connecting them to the member; and their width shall be in accordance with American Bridge Company's standards, generally: **Lacing.**

| | |
|---|---|
| For 15-inch channels, or built sections with $3\frac{1}{2}$ and 4-inch angles. | $2\frac{1}{2}$ inches ($\frac{7}{8}$ inch rivets). |
| For 12, 10 and 9-inch channels, or built sections with 3-inch angles. | $2\frac{1}{4}$ inches ($\frac{3}{4}$ inch rivets). |
| For 8 and 7-inch channels, or built sections with $2\frac{1}{2}$ inch angles. | 2 inches ($\frac{5}{8}$ inch rivets). |
| For 6- and 5-inch channels, or built sections with 2-inch angles. | $1\frac{3}{4}$ inches ($\frac{1}{2}$ inch rivets.) |

72. All pin-holes shall be re-enforced by additional material when necessary, so as not to exceed the allowed pressure on the pins. These re-enforcing plates must contain enough rivets to transfer the proportion of pressure which comes upon them, and at least one plate on each side shall extend not less than 6 inches beyond the edge of the tie plate. **Pin Plates.**

73. Web plates of girders must be spliced at all joints by a plate on each side of the web, capable of transmitting the full strain through splice rivets. **Web Splices.**

74. The flange plates of all girders must be limited in width so as not to extend beyond the outer lines of rivets connecting them with the angles, more than five inches or more than eight times the thickness of the first plate. Where two or more plates are used on the flanges, they shall either be of equal thickness or shall decrease in thickness outward from the angles. **Flange Plates.**

## WORKMANSHIP.

**Riveted Work Punching.** 75. All riveted work shall be punched accurately with holes 1-16 of an inch larger than the size of the rivet, and when the pieces forming one built member are put together, the holes must be truly opposite; no drifting to distort the metal will be allowed; if the hole must be enlarged to admit the rivet, it must be reamed.

**Holes for Field Rivets.** 76. All holes for field rivets in floorbeam and stringer connections and splices in tension members, shall be accurately drilled to an iron templet or reamed while the connecting parts are temporarily put together.

**Planing and Reaming.** 77. In medium steel over $\frac{3}{4}$ of an inch thick, all sheared edges shall be planed, and all holes shall be drilled or reamed to a diameter of $\frac{1}{8}$ of an inch larger than the punched holes, so as to remove all the sheared surface of the metal.

**Rivets.** 78. The rivet heads must be of approved hemispherical shape, and of a uniform size for the same size rivets throughout the work. They must be full and neatly finished throughout the work and concentric with the rivet hole.

79. All rivets when driven must completely fill the holes, the heads be in full contact with the surface, or countersunk when so required.

**Riveters.** 80. Wherever possible, all rivets shall be machine driven. Power riveters shall be direct-acting machines, worked by steam, hydraulic pressure, or compressed air.

**Bolts.** 81. When members are connected by bolts which transmit shearing strains, such bolts must have a driving fit.

**Neat Finish.** 82. The several pieces forming one built member must fit closely together, and when riveted shall be free from twists, bends, or open joints.

83. All portions of the work exposed to view shall be neatly finished.

**Contact Surfaces.** 84. All surfaces in contact shall be painted before they are put together.

**Forged Work Eye-Bars.** 85. The heads of eye-bars shall be made by upsetting, rolling, or forging into shape. Welds in the body of the bar will not be allowed.

86. The bars must be perfectly straight before boring.

87. The holes shall be in the centre of the head and on the centre line of the bar.

88. All eye-bars shall be annealed.

89. All abutting surfaces in compression members shall be truly faced to even bearings, so that they shall be in such contact throughout as may be obtained by such means. **Machine Work Facing.**

90. The ends of riveted floor girders shall be faced true and square.

91. Pin holes shall be bored truly parallel with one another and at right angles to the axis of the member unless otherwise shown in drawings; and in pieces not adjustable for length, no variation of more than 1-64 of an inch for every 20 feet will be allowed in the length between centres of pin holes. **Pin Holes.**

92. Bars which are to be placed side by side in the structure shall be bored at the same temperature, and shall be of such equal length that, upon being piled on each other, the pins shall pass through the holes at both ends at the same time without driving.

93. All pins shall be accurately turned to a gauge, and shall be straight and smooth. **Pins.**

94. The clearance between pin and pin hole shall be 1-50 of an inch for pins up to $3\frac{1}{2}$ inches in diameter, which amount shall be gradually increased to 1-32 of an inch for pins 6 inches in diameter and over. **Play in Pin Holes.**

95. All pins shall be supplied with steel pilot nuts, for use during erection. **Pilot Nuts.**

96. All workmanship shall be first-class in every particular. **Workmanship.**

## STEEL.

97. All steel must be made by the Open Hearth process, and if by acid process, shall contain not more than .08 per cent. of phosphorus, and if by basic process, not more than .05 per cent. of phosphorus, and must be uniform in character for each specified kind. **Process of Manufacture.**

98. The finished bars, plates and shapes, must be free from injurious seams, flaws or cracks, and have a clean, smooth finish. **Finish.**

99. The tensile strength, limit of elasticity and ductility, shall be determined from a standard test- **Test Pieces.**

piece, cut from the finished material, of at least ½ square inch section. All broken samples must show a silky fracture of uniform color.

**Annealed Test Pieces.**

100. Material which is to be used without annealing or further treatment is to be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material is to be similarly treated before testing.

**Marking.**

101. Every finished piece of steel shall be stamped with the blow number identifying the melt.

**Physical Properties.**

102. Steel shall be of three grades: *Rivet, Soft* and *Medium.*

**Rivet Steel.**

103. *Rivet Steel* shall have: Ultimate strength, 48,000 to 58,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 26 per cent. Bending test, 180 degrees flat on itself, without fracture on outside of bent portion.

**Soft Steel.**

104. *Soft Steel* shall have: Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 25 per cent. Bending test, 180 degrees flat on itself, without fracture on outside of bent portion.

**Medium Steel.**

105. *Medium Steel* shall have: Ultimate strength, 60,000 to 70,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 22 per cent. Bending test, 180 degrees to a diameter equal to thickness of piece tested, without fracture on outside of bent portion.

**Full Size Test of Steel Eye-Bars.**

106. Full size test of steel eye-bars shall be required to show not less than 10 per cent. elongation in the body of the bar, and tensile strength not more than 5,000 pounds below the mimimum tensile strength required in specimen tests of the grade of steel from which they are rolled. The bars will be required to break in the body but should a bar break in the head, but develop 10 per cent, elongation and the ultimate strength specified, it shall not be cause for rejection, provided not more than one-third of the total number of bars tested break in the head; otherwise the entire lot will be rejected.

**Pin Steel.**

107. Pins made of either of the above mentioned grades of steel shall, on specimen test pieces

cut from finished material, fill the requirements of the grade of steel from which they are rolled, excepting the elongation, which shall be decreased 5 per cent, from that specified.

108. Punched rivet holes, pitched two diameters from a sheared edge, must stand drifting until the diameter is one third larger than the original hole, without cracking the metal. Drifting

109. The slabs for rolling plates shall be rolled from ingots of at least twice their cross-section. Slabs for Plates.

110. Pins up to 7 inches diameter shall be rolled. Pins.

111. Pins exceeding 7 inches diameter shall be forged under a steel hammer striking a blow of at least 5 tons. The blooms to be used for this purpose shall have at least three times the sectional area of the finished pins.

112. A variation in cross-section or weight of rolled material of more than $2\frac{1}{2}$ per cent. from that specified, may be cause for rejection. Variation in Weight.

113. Steel casting shall be made of Open Hearth Steel containing from .25 to .40 per cent. carbon and not over .08 per cent. of phosphorus, and shall be practically free from blow holes. Steel Castings

114. Except where chilled iron is specified, all castings shall be of tough, gray iron, free from injurious cold shuts or blow holes, true to pattern, and of workmanlike finish. Test bars one inch square, loaded in middle between supports 12 inches apart, shall bear 2,500 pounds or over, and deflect 0.15 of an inch before rupture. Cast Iron.

## TIMBER.

Timber.

115. The timber shall be strictly first-class spruce, white pine, Douglas fir, Southern yellow pine, or white oak bridge timber; sawed true and out of wind, full size, free from wind shakes, large or loose knots, decayed or sapwood, wormholes or other defects impairing its strength or durability.

## PAINTING.

Painting.

116. All iron work before leaving the shop shall be thoroughly cleaned from all loose scale and rust, and be given one good coating of pure boiled linseed oil, well worked into all joints and open spaces.

117. In riveted work, the surfaces coming in contact shall each be painted before being riveted together.

118. Pieces which are not accessible for painting after erection shall have two coats of paint.

119. The paint shall be of good quality of oxide of iron paint, mixed with pure linseed oil, or such as may be specified in contract.

120. After the structure is erected, the iron work shall be thoroughly and evenly painted with two additional coats of paint, mixed with pure linseed oil, of such quality and color as may be selected.

121. Pins, pin holes, screw threads and other finished surfaces shall be coated with white lead and tallow before being shipped from the shop.

## INSPECTION.

Inspection.

122. All facilities for inspection of material and workmanship shall be furnished by the contractor to competent inspectors, and the engineer and his inspectors shall be allowed free access to any part of the works in which any portion of the material is made.

123. The contractor shall furnish, without charge, such specimens (prepared) of the several kinds of material to be used as may be required to determine their character.

## TESTING.

124. Full sized parts of the structure may be tested at the option of the purchaser; but, if tested to destruction, such material shall be paid for at cost, less its scrap value, if it proves satisfactory. Testing.

125. If it does not stand the specified tests, it will be considered rejected material, and be solely at the cost of the contractor, unless he is not responsible for the design of the work.

## GENERAL DATA

For bridge over .............................at
........town of...............State of.........
Length and general description:.................
........... ......... .................
........... ......... .................
Skew, or angle of current with centre line of bridge
........... ......... .................
Width of Roadway............................
Number and width of Footwalks.................
Class of Bridge.....floor (solid or planking, etc)..
Stringers ......... .........................
Number of Street Car Tracks....................
Location " " " " ....................
Dimensions of Bridge Seat and Piers, if built......
........... ......... .................
Distance Floor to High Water..................
" " " Low " ................
Depth of Low Water.................. ........
" " Ordinary Stage .........................
Distance Top of Floor to Lowest Point of Steel
Work, if fixed by local conditions............
Character of River Bottom......................
Are Piles necessary for False Work?............
Distance to be Hauled...........................
Name of nearest Railroad Station................
Remarks .............. ......................
........... ......... .................

TABLE I.

UNIFORM LIVE LOAD FOR THE TRUSSES.

| CLASS A. | | | CLASS B. | | |
|---|---|---|---|---|---|
| Span in feet | Pounds per Lineal Foot of each Street Car Track | Pounds per Square Foot of remaining Floor Surface | Span in feet | Pounds per Lineal Foot of each Street Car Track | Pounds per Square Foot of remaining Floor Surface |
| UP TO 100 | 1800 | 100 | UP TO 100 | 1800 | 80 |
| 105 | 1770 | 99 | 105 | 1770 | 79 |
| 110 | 1740 | 98 | 110 | 1740 | 78 |
| 115 | 1710 | 97 | 115 | 1710 | 77 |
| 120 | 1680 | 96 | 120 | 1680 | 76 |
| 125 | 1650 | 95 | 125 | 1650 | 75 |
| 130 | 1620 | 94 | 130 | 1620 | 74 |
| 135 | 1590 | 93 | 135 | 1590 | 73 |
| 140 | 1560 | 92 | 140 | 1560 | 72 |
| 145 | 1530 | 91 | 145 | 1530 | 71 |
| 150 | 1500 | 90 | 150 | 1500 | 70 |
| 155 | 1470 | 89 | 155 | 1470 | 69 |
| 160 | 1440 | 88 | 160 | 1440 | 68 |
| 165 | 1410 | 87 | 165 | 1410 | 67 |
| 170 | 1380 | 86 | 170 | 1380 | 66 |
| 175 | 1350 | 85 | 175 | 1350 | 65 |
| 180 | 1320 | 84 | 180 | 1320 | 64 |
| 185 | 1290 | 83 | 185 | 1290 | 63 |
| 190 | 1260 | 82 | 190 | 1260 | 62 |
| 195 | 1230 | 81 | 195 | 1230 | 61 |
| 200 AND OVER | 1200 | 80 | 200 AND OVER | 1200 | 60 |

CLASS C.

| | | | | | |
|---|---|---|---|---|---|
| UP TO 100 | 1200 | 80 | 155 | 1090 | 69 |
| 105 | 1190 | 79 | 160 | 1080 | 68 |
| 110 | 1180 | 78 | 165 | 1070 | 67 |
| 115 | 1170 | 77 | 170 | 1060 | 66 |
| 120 | 1160 | 76 | 175 | 1050 | 65 |
| 125 | 1150 | 75 | 180 | 1040 | 64 |
| 130 | 1140 | 74 | 185 | 1030 | 63 |
| 135 | 1130 | 73 | 190 | 1020 | 62 |
| 140 | 1120 | 72 | 195 | 1010 | 61 |
| 145 | 1110 | 71 | 200 AND OVER | 1000 | 60 |
| 150 | 1100 | 70 | | | |

TABLE I.—(CONTINUED.)

UNIFORM LIVE LOAD FOR THE TRUSSES.

| CLASS D. | | CLASS E | | CLASS $E_2$ | |
|---|---|---|---|---|---|
| Span in feet | Pounds per Square foot of Floor Surface | Span in feet | Pounds per Lineal Foot of each Car Track | Span in feet | Pounds per Lineal Foot of each Car Track |
| UP TO 75 | 80 | UP TO 100 | 1800 | UP TO 100 | 1200 |
| 80 | 79 | 105 | 1770 | 105 | 1190 |
| 85 | 78 | 110 | 1740 | 110 | 1180 |
| 90 | 77 | 115 | 1710 | 115 | 1170 |
| 95 | 76 | 120 | 1680 | 120 | 1160 |
| 100 | 75 | 125 | 1650 | 125 | 1150 |
| 105 | 74 | 130 | 1620 | 130 | 1140 |
| 110 | 73 | 135 | 1590 | 135 | 1130 |
| 115 | 72 | 140 | 1560 | 140 | 1120 |
| 120 | 71 | 145 | 1530 | 145 | 1110 |
| 125 | 70 | 150 | 1500 | 150 | 1100 |
| 130 | 69 | 155 | 1470 | 155 | 1090 |
| 135 | 68 | 160 | 1440 | 160 | 1080 |
| 140 | 67 | 165 | 1410 | 165 | 1070 |
| 145 | 66 | 170 | 1380 | 170 | 1060 |
| 150 | 65 | 175 | 1350 | 175 | 1050 |
| 155 | 64 | 180 | 1320 | 180 | 1040 |
| 160 | 63 | 185 | 1290 | 185 | 1030 |
| 165 | 62 | 190 | 1260 | 190 | 1020 |
| 170 | 61 | 195 | 1230 | 195 | 1010 |
| 175 | 60 | 200 AND OVER | 1200 | 200 AND OVER | 1000 |
| 180 | 59 | | | | |
| 185 | 58 | | | | |
| 190 | 57 | | | | |
| 195 | 56 | | | | |
| 200 AND OVER | 55 | | | | |

TABLE II.

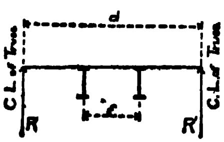
MAXIMUM MOMENTS M, END SHEARS S, AND FLOORBEAM REACTIONS R, PER STRINGER FOR A CONCENTRATED LOAD OF 24, 18, 12 AND 6 TONS ON 2 AXLES 10 FEET CENTRES.

| Span L in feet | 24 TONS | | 18 TONS | | 12 TONS | | 6 TONS | | Span L in feet |
|---|---|---|---|---|---|---|---|---|---|
| | Road and Track Stringers of Class A — Track Stringers of Class B — Track Stringers of Class E1 | | Track Stringers of Class C — Track Stringers of Class E2 | | Road Stringers of Class B — Road Stringers of Class C | | Road Stringers of Class D | | |
| | S=R in lbs. | M in foot lbs. | S=R in lbs. | M in foot lbs. | S=R in lbs. | M in foot lbs. | S=R in lbs. | M in foot lbs. | |
| 10 | 12000 | 30000 | 9000 | 22500 | 6000 | 15000 | 3000 | 7500 | 10 |
| 11 | 13000 | 33000 | 9800 | 24800 | 6500 | 16500 | 3300 | 8300 | 11 |
| 12 | 14000 | 36000 | 10500 | 27000 | 7000 | 18000 | 3500 | 9000 | 12 |
| 13 | 14800 | 39000 | 11100 | 29300 | 7400 | 19500 | 3700 | 9800 | 13 |
| 14 | 15400 | 42000 | 11600 | 31500 | 7700 | 21000 | 3900 | 10500 | 14 |
| 15 | 16000 | 45000 | 12000 | 33800 | 8000 | 22500 | 4000 | 11300 | 15 |
| 16 | 16500 | 48000 | 12400 | 36000 | 8300 | 24000 | 4100 | 12000 | 16 |
| 17 | 16900 | 51000 | 12700 | 38300 | 8500 | 25500 | 4200 | 12800 | 17 |
| 18 | 17300 | 56300 | 13000 | 42300 | 8700 | 28100 | 4300 | 14000 | 18 |
| 19 | 17700 | 61900 | 13300 | 46500 | 8800 | 31000 | 4400 | 15500 | 19 |
| 20 | 18000 | 67500 | 13500 | 50600 | 9000 | 33800 | 4500 | 16900 | 20 |
| 21 | 18300 | 73100 | 13700 | 54900 | 9100 | 36600 | 4600 | 18300 | 21 |
| 22 | 18500 | 78800 | 13900 | 59000 | 9300 | 39400 | 4600 | 19700 | 22 |
| 23 | 18800 | 84500 | 14100 | 63400 | 9400 | 42300 | 4700 | 21100 | 23 |
| 24 | 19000 | 90300 | 14300 | 67700 | 9500 | 45100 | 4800 | 22600 | 24 |
| 25 | 19200 | 96000 | 14400 | 72000 | 9600 | 48000 | 4800 | 24000 | 25 |
| 26 | 19400 | 101800 | 14500 | 76300 | 9700 | 50900 | 4800 | 25400 | 26 |
| 27 | 19600 | 107600 | 14700 | 80700 | 9800 | 53800 | 4900 | 26900 | 27 |
| 28 | 19700 | 113400 | 14800 | 85000 | 9900 | 56700 | 4900 | 28300 | 28 |
| 29 | 19900 | 119200 | 14900 | 89400 | 9900 | 59600 | 5000 | 29800 | 29 |
| 30 | 20000 | 125000 | 15000 | 93800 | 10000 | 62500 | 5000 | 31300 | 30 |
| 31 | 20100 | 130800 | 15100 | 98100 | 10100 | 65400 | 5000 | 32700 | 31 |
| 32 | 20300 | 136700 | 15200 | 102500 | 10100 | 68300 | 5100 | 34200 | 32 |
| 33 | 20400 | 142500 | 15300 | 106900 | 10200 | 71300 | 5100 | 35600 | 33 |
| 34 | 20500 | 148400 | 15400 | 111300 | 10200 | 74200 | 5100 | 37100 | 34 |
| 35 | 20600 | 154300 | 15400 | 115700 | 10300 | 77100 | 5100 | 38600 | 35 |
| 36 | 20700 | 160200 | 15500 | 120100 | 10300 | 80100 | 5200 | 40000 | 36 |
| 37 | 20800 | 166100 | 15600 | 124500 | 10400 | 83000 | 5200 | 41500 | 37 |
| 38 | 20800 | 172000 | 15600 | 129000 | 10400 | 86000 | 5200 | 43000 | 38 |
| 39 | 20900 | 177800 | 15700 | 133400 | 10500 | 88900 | 5200 | 44500 | 39 |
| 40 | 21000 | 183800 | 15800 | 137800 | 10500 | 91900 | 5300 | 45900 | 40 |

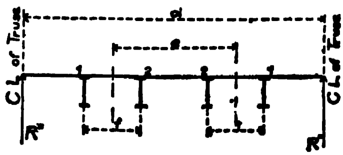
## TABLE III.

**MAXIMUM END REACTIONS R OF FLOORBEAMS OF CLASSES $E_1$ AND $E_2$ FOR SINGLE AND DOUBLE TRACK.**

SINGLE TRACK




DOUBLE TRACK




Floorbeam Moment $= \frac{R'}{2}(d-f)$

| Length L in ft. | R' IN POUNDS. Class E1 24 Tons | R' IN POUNDS. Class E2 18 Tons | Length L in ft. | R'' IN POUNDS. Class E1 24 Tons | R'' IN POUNDS. Class E2 18 Tons |
|---|---|---|---|---|---|
| 10 | 12000 | 9000 | 10 | 24000 | 18000 |
| 11 | 13100 | 9800 | 11 | 26200 | 19600 |
| 12 | 14000 | 10500 | 12 | 28000 | 21000 |
| 13 | 14800 | 11100 | 13 | 29600 | 22200 |
| 14 | 15400 | 11600 | 14 | 30800 | 23200 |
| 15 | 16000 | 12000 | 15 | 32000 | 24000 |
| 16 | 16500 | 12400 | 16 | 33000 | 24800 |
| 17 | 16900 | 12700 | 17 | 33800 | 25400 |
| 18 | 17300 | 13000 | 18 | 34600 | 26000 |
| 19 | 17700 | 13300 | 19 | 35400 | 26600 |
| 20 | 18000 | 13500 | 20 | 36000 | 27000 |
| 21 | 18300 | 13700 | 21 | 36600 | 27400 |
| 22 | 18500 | 13900 | 22 | 37000 | 27800 |
| 23 | 18800 | 14100 | 23 | 37600 | 28200 |
| 24 | 19000 | 14300 | 24 | 38000 | 28600 |
| 25 | 19200 | 14400 | 25 | 38400 | 28800 |
| 26 | 19400 | 14500 | 26 | 38800 | 29000 |
| 27 | 19600 | 14700 | 27 | 39200 | 29400 |
| 28 | 19700 | 14800 | 28 | 39400 | 29600 |
| 29 | 19900 | 14900 | 29 | 39800 | 29800 |
| 30 | 20000 | 15000 | 30 | 40000 | 30000 |
| 31 | 20100 | 15100 | 31 | 44200 | 30200 |
| 32 | 20300 | 15200 | 32 | 40600 | 30400 |
| 33 | 20400 | 15300 | 33 | 40800 | 30600 |
| 34 | 20500 | 15400 | 34 | 41000 | 30800 |
| 35 | 20600 | 15400 | 35 | 41200 | 30800 |
| 36 | 20700 | 15500 | 36 | 41400 | 31000 |
| 37 | 20800 | 15600 | 37 | 41600 | 31200 |
| 38 | 20800 | 15600 | 38 | 41600 | 31200 |
| 39 | 20900 | 15700 | 39 | 41800 | 31400 |
| 40 | 21000 | 15800 | 40 | 42000 | 31600 |

Floorbeam Moment at $\begin{cases} 1\ldots = \frac{R''}{2}(d-e-f) \\ 2\ldots = \frac{R''}{2}(d-e) \end{cases}$

TABLE IV.

STANDARD BEAM BRIDGES FOR CLASS D.

| Length out to out of Beams. | 12' WIDE. | 14' WIDE. | 16' WIDE. | 18' WIDE. | 20' WIDE. | 22' WIDE. |
|---|---|---|---|---|---|---|
| 10' to 14' | 3—7" Is 15 lb.<br>2—7" [s 9¾ lb. | 4—7" Is 15 lb.<br>2—7" [s 9¾ lb. | 5—7" Is 15 lb.<br>2—7" [s 9¾ lb. | 5—7" Is 15 lb.<br>2—7" [s 9¾ lb. | 6—7" Is 15 lb.<br>2—7" [s 9¾ lb. | 6—7" Is 15 lb.<br>2—7" [s 9¼ lb. |
| 15' to 18' | 3—8" Is 18 lb.<br>2—8" [s 11¼ lb. | 4—8" Is 18 lb.<br>2—8" [s 11¼ lb. | 5—8" Is 18 lb.<br>2—8" [s 11¼ lb. | 5—8" Is 18 lb.<br>2—8" [s 11¼ lb. | 6—8" Is 18 lb.<br>2—8" [s 11¼ lb. | 6—8" Is 18 lb.<br>2—8" [s 11¼ lb. |
| 19' to 22' | 3—9" Is 21 lb.<br>2—9" [s 13¼ lb. | 4—9" Is 21 lb.<br>2—9" [s 13¼ lb. | 5—9" Is 21 lb.<br>2—9" [s 13¼ lb. | 5—9" Is 21 lb.<br>2—9" [s 13¼ lb. | 6—9" Is 21 lb.<br>2—9" [s 13¼ lb. | 6—9" Is 21 lb.<br>2—9" [s 13¼ lb. |
| 23' to 26' | 3—10" Is 25 lb.<br>2—10" [s 15 lb. | 4—10" Is 25 lb.<br>2—10" [s 15 lb. | 5—10" Is 25 lb.<br>2—10" [s 15 lb. | 5—10" Is 25 lb.<br>2—10" [s 15 lb. | 6—10" Is 25 lb.<br>2—10" [s 15 lb. | 6—10" Is 25 lb.<br>2—10" [s 15 lb. |
| 27' to 30' | 3—12" Is 31½ lb.<br>2—12" [s 20½ lb. | 4—12" Is 31½ lb.<br>2—12" [s 20½ lb. | 5—12" Is 31½ lb.<br>2—12" [s 20½ lb. | 5—12" Is 31½ lb.<br>2—12" [s 20½ lb. | 6—12" Is 31½ lb.<br>2—12" [s 20½ lb. | 6—12" Is 31½ lb.<br>2—12" [s 20½ lb. |
| 31' to 35' | 3—15" Is 42 lb.<br>2—15" [s 33 lb. | 4—15" Is 42 lb.<br>2—15" [s 33 lb. | 5—15" Is 42 lb.<br>2—15" [s 33 lb. | 5—15" Is 42 lb.<br>2—15" [s 33 lb. | 6—15" Is 42 lb.<br>2—15" [s 33 lb. | 6—15" Is 42 lb.<br>2—15" [s 33 lb. |
| 36' to 40' | 5—18" Is 55 lb. | 6—18" Is 55 lb. | 7—18" Is 55 lb. | 7—18" Is 55 lb. | 8—18" Is 55 lb. | 8—18" Is 55 lb. |

NOTE—Clear span under Coping is 2 feet less than length out to out of beams.

TABLE V.

PERMISSIBLE COMPRESSIVE STRAINS.

p=strain allowed in lbs. per sq. in.; l=length; r=least radius of gyration; (both in inches).

Soft steel; $p=\dfrac{15{,}000}{1+\dfrac{l^2}{13{,}500r^2}}$ Medium steel; $p=\dfrac{17{,}000}{1+\dfrac{l^2}{11{,}000r^2}}$

| $\frac{l}{r}$ | Soft Steel | Med Steel | $\frac{l}{r}$ | Soft Steel | Med Steel | $\frac{l}{r}$ | Soft Steel | Med Steel |
|---|---|---|---|---|---|---|---|---|
| 10 | 14900 | 16850 | 50 | 12660 | 13850 | 90 | 9370 | 9790 |
| 12 | 14840 | 16780 | 52 | 12500 | 13650 | 92 | 9220 | 9610 |
| 14 | 14780 | 16710 | 54 | 12340 | 13440 | 94 | 9060 | 9420 |
| 16 | 14720 | 16610 | 56 | 12180 | 13230 | 96 | 8910 | 9240 |
| 18 | 14650 | 16510 | 58 | 12010 | 13020 | 98 | 8760 | 9080 |
| 20 | 14560 | 16410 | 60 | 11840 | 12810 | 100 | 8610 | 8910 |
| 22 | 14480 | 16290 | 62 | 11670 | 12600 | 102 | 8470 | 8740 |
| 24 | 14400 | 16150 | 64 | 11500 | 12390 | 104 | 8320 | 8570 |
| 26 | 14280 | 16020 | 66 | 11340 | 12180 | 106 | 8180 | 8410 |
| 28 | 14180 | 15870 | 68 | 11140 | 11970 | 108 | 8050 | 8250 |
| 30 | 14070 | 15710 | 70 | 11010 | 11760 | 110 | 7900 | 8100 |
| 32 | 13940 | 15550 | 72 | 10840 | 11550 | 112 | 7780 | 7940 |
| 34 | 13810 | 15380 | 74 | 10670 | 11350 | 114 | 7640 | 7790 |
| 36 | 13690 | 15210 | 76 | 10500 | 11150 | 116 | 7510 | 7650 |
| 38 | 13550 | 15030 | 78 | 10340 | 10950 | 118 | 7380 | 7500 |
| 40 | 13420 | 14840 | 80 | 10180 | 10750 | 120 | 7260 | 7360 |
| 42 | 13270 | 14650 | 82 | 10010 | 10550 | 125 | 6950 | 7020 |
| 44 | 13120 | 14460 | 84 | 9850 | 10350 | 130 | 6660 | 6700 |
| 46 | 12960 | 14260 | 86 | 9690 | 10160 | 135 | 6380 | 6400 |
| 48 | 12820 | 14060 | 88 | 9530 | 9970 | 140 | 6120 | 6110 |

## TABLE VI.

### MAXIMUM BENDING MOMENTS ON PINS.

**With extreme Fibre Strains of 22000 pounds per square inch for Soft Steel, and 25000 pounds per square inch for Medium Steel.**

| Diam. of Pin in Inches. | Area of Pin in Square Inches. | Moments in Inch-Pounds. | | Diam. of Pin in Inches. | Area of Pin in Square Inches. | Moments in Inch-Pounds. | |
|---|---|---|---|---|---|---|---|
| | | 22000 lbs. per sq. in. | 25000 lbs. per sq in. | | | 22000 lbs. per sq. in. | 25000 lbs. per sq. in. |
| 2 | 3.142 | 17280 | 19600 | 6½ | 33.183 | 593100 | 674000 |
| 2⅛ | 3.547 | 20730 | 23600 | 6⅝ | 34.472 | 628000 | 713700 |
| 2¼ | 3.976 | 24600 | 28000 | 6¾ | 35.785 | 664200 | 754800 |
| 2⅜ | 4.430 | 28900 | 32900 | 6⅞ | 37.122 | 701800 | 797500 |
| 2½ | 4.909 | 33700 | 38400 | 7 | 38.485 | 740800 | 841900 |
| 2⅝ | 5.412 | 39000 | 44400 | 7⅛ | 39.871 | 781200 | 887800 |
| 2¾ | 5.940 | 44900 | 51000 | 7¼ | 41.282 | 823000 | 935300 |
| 2⅞ | 6.492 | 51300 | 58300 | 7⅜ | 42.718 | 866300 | 984500 |
| 3 | 7.069 | 58300 | 66300 | 7½ | 44.179 | 911200 | 1035400 |
| 3⅛ | 7.670 | 65900 | 74900 | 7⅝ | 45.664 | 957500 | 1088100 |
| 3¼ | 8.296 | 74100 | 84300 | 7¾ | 47.173 | 1005300 | 1142500 |
| 3⅜ | 8.946 | 83000 | 94400 | 7⅞ | 48.707 | 1054800 | 1198700 |
| 3½ | 9.621 | 92600 | 105200 | 8 | 50.265 | 1105800 | 1256600 |
| 3⅝ | 10.321 | 102900 | 116900 | 8⅛ | 51.849 | 1158500 | 1316500 |
| 3¾ | 11.045 | 113900 | 129400 | 8¼ | 53.456 | 1212800 | 1378200 |
| 3⅞ | 11.793 | 125600 | 142800 | 8⅜ | 55.088 | 1268800 | 1441800 |
| 4 | 12.566 | 138200 | 157100 | 8½ | 56.745 | 1326400 | 1507300 |
| 4⅛ | 13.364 | 151600 | 172300 | 8⅝ | 58.426 | 1385800 | 1574800 |
| 4¼ | 14.186 | 165800 | 188400 | 8¾ | 60.132 | 1446900 | 1644200 |
| 4⅜ | 15.033 | 180800 | 205500 | 8⅞ | 61.862 | 1509800 | 1715700 |
| 4½ | 15.904 | 196800 | 223700 | 9 | 63.617 | 1574500 | 1789200 |
| 4⅝ | 16.800 | 213700 | 242800 | 9⅛ | 65.397 | 1641100 | 1864800 |
| 4¾ | 17.721 | 231500 | 263000 | 9¼ | 67.201 | 1709400 | 1942500 |
| 4⅞ | 18.665 | 250200 | 284000 | 9⅜ | 69.029 | 1779600 | 2022300 |
| 5 | 19.635 | 270000 | 306800 | 9½ | 70.882 | 1851800 | 2104300 |
| 5⅛ | 20.629 | 290700 | 330400 | 9⅝ | 72.760 | 1925900 | 2188500 |
| 5¼ | 21.648 | 312500 | 355200 | 9¾ | 74.662 | 2001900 | 2274900 |
| 5⅜ | 22.691 | 335400 | 381100 | 9⅞ | 76.590 | 2079900 | 2363500 |
| 5½ | 23.758 | 359300 | 408300 | 10 | 78.54 | 2159900 | 2454400 |
| 5⅝ | 24.850 | 384400 | 436800 | 10¼ | 82.52 | 2325900 | 2643100 |
| 5¾ | 25.967 | 410600 | 466600 | 10½ | 86.59 | 2500200 | 2841200 |
| 5⅞ | 27.109 | 438000 | 497700 | 10¾ | 90.76 | 2683200 | 3049100 |
| 6 | 28.274 | 466500 | 530200 | 11 | 95.03 | 2874800 | 3266800 |
| 6⅛ | 29.465 | 496300 | 564000 | 11¼ | 99.40 | 3075400 | 3494800 |
| 6¼ | 30.680 | 527300 | 599200 | 11½ | 103.87 | 3284800 | 3732800 |
| 6⅜ | 31.919 | 559600 | 635900 | 12 | 113.10 | 3732200 | 4241200 |

drawbridge machinery. Cast iron will be used for minor details of drawbridge machinery, and for other work when expressly stipulated.

Standard Designs.

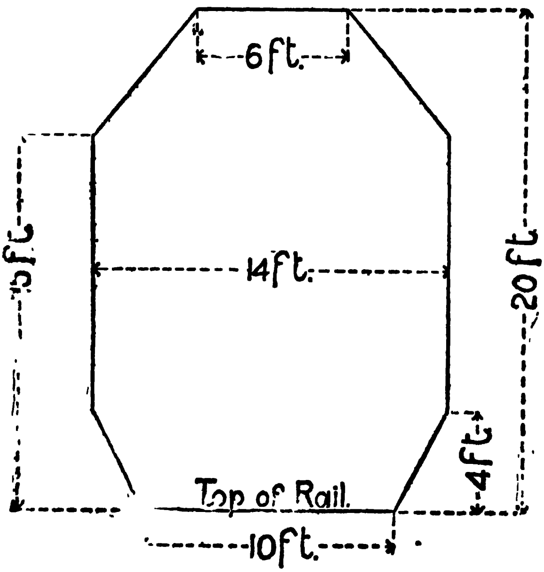
2. Rolled-beam bridges and plate-girder bridges will in general conform to the Pennsylvania Railroad Company's standard drawings. The Railroad Company will furnish diagrams showing the general dimensions of all truss bridges and of such special girder spans as are not covered by standard drawings.

Guage of Track.

3. Gauge of track is 4 feet $8\frac{1}{2}$ inches. Distance from centre to centre of double track is 12 feet 2 inches unless otherwise specified.

Clear Cross-Section. Truss Bridges.

4. A section as per accompanying diagram must be kept clear in single-track through bridges. Width to be proportionately increased for two or more tracks, and for curved line.




### SECTION 2.—DATA FOR CALCULATION.

Assumed Dimensions.

5. As a basis for calculation assume the following general dimensions:—

A—Length:—

(1.) Trusses.—Distance from centre to centre of end pins.

(2.) Riveted girders.—Distance from centre to centre of bearings.
(3.) Floor beams.—Distance from centre to centre of trusses.
(4.) Track stringers.—Distance from centre to centre of floor beams.

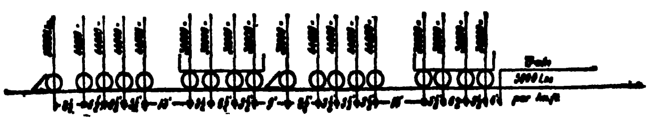
B—Depth:—
(1.) Pin-connected trusses.—Distance from centre to centre of chord pins.
(2.) Riveted trusses.—Distance between centres of gravity of chords.
(3.) Riveted girders.—Distance between centres of gravity of flanges, or distance from back to back of flange angles if the latter dimension is the smaller of the two.

6. In estimating the dead load the weight of timber shall be taken at 4½ pounds per foot B. M. **Weight of Timber.**

7. The dead load shall be assumed as uniformly distributed and made up of:— **Dead Load.**
(1.) The net suspended weight of metal in the trusses and bracing.
(2.) The weight of the metal floor system (if any.)
(3.) The weight of the wooden cross-ties or floor beams.
(4.) 160 pounds per lineal foot of track, covering the weight of rails, splices, guard rails, &c.

The above items of dead load to be properly distributed between the panel points of the loaded and the unloaded chords.

8. In addition to the dead load, bridges shall be designed to carry on each track a moving load consisting of two coupled "Consolidation" engines, as shown in the following diagram, followed by a uniformly distributed train load of 5000 pounds per **Live Load.**



lineal foot of track; the moving load to be so placed as to produce the greatest stress in each member of the structure.[1]

**Note.—For all track stringers and floor beams, and for plate-girder spans not exceeding 110 feet in length, the maximum calculated stresses due to live load are given in Table A.**

Wind Loads. 9. The wind pressure shall be assumed, acting horizontally in either direction:—

(1.) At 30 pounds per square foot on the exposed surface of all trusses and the floor as seen in elevation, and on the side of a train 10 feet high, beginning at $2\frac{1}{2}$ feet above the base of rail and moving across the bridge.

(2.) At 50 pounds per square foot on all exposed surfaces of the unloaded structure.

The greater calculated stress will be used in proportioning the wind bracing.

Anchorage. 10. For determining the requisite anchorage for the loaded structure the train shall be assumed to weigh 800 pounds per lineal foot.

Longitudinal Bracing of Trestle Towers to Resist Momentum of Train. 11. For longitudinal bracing of trestle towers and similar structures, the momentum produced by suddenly stopping the train shall be considered; the coefficient of friction of wheels sliding upon rails being assumed as 0.2.

Stresses Due to Centrifugal Force. 12. When the structure is on a curve the effect due to the centrifugal force of as many trains as there are tracks shall be provided for (see Table G).

SECTION 3.—DETERMINATION OF SECTIONS.

Strain Sheet. 13. The calculation of stresses produced by the above-mentioned live and dead loads will determine the following values for each member:—

M = Maximum calculated stress in member (compress or tension).

m = (1), Minimum calculated stress in members subjected to one kind of stress only (all compression or all tension); or (2), maximum calcu-

[1] This corresponds closely with Cooper's "E40" loading, except that we have here a train load of 5,000 lbs. per lin. ft., where Cooper has for this case 4,000 lbs.

lated stress of lesser kind, in members subjected to reversal of stress.

NOTE.—Minimum stress is understood to mean the absolute minimum; *i. e.*, in a main diagonal or post of a simple span "m" equals the calculated dead-load stress minus the maximum calculated counter stress due to live load.

$$R=\frac{m}{M}$$

14. The maximum calculated stress (M) in each member shall be multiplied by the coefficient $(1+k)$, and the resultant quantity, $M(1+k)$, shall be regarded as the equivalent static stress in the member. (For the value of k see Tables B and C.) **Stress Increment Due to Impact, &c.**

15. All members shall be so proportioned that the stress, $M(1+k)$, shall not cause the tensile unit stress to exceed 15,000 pounds, nor the compressive unit stress to exceed 15,000 pounds properly reduced in accordance with Clause 16. **Permissible Tensile Unit Stress**

16. For compression members, the unit stress of 15,000 pounds per square inch shall be reduced in proportion to the ratio of the length to the least radius of gyration of the section, by the following formula:— **Permissible Compressive Unit Stress**

$$p=\frac{15.000}{1+\frac{l^2}{13{,}500r^2}}$$

Where $\begin{cases} p=\text{permissible working stress per square inch in compression.} \\ l=\text{length of piece in inches between centres of connections.} \\ r=\text{least radius ot gyration of section in inches.} \end{cases}$

(See Table D.)

17. The net section of the long hip-verticals of through bridges shall be 25 per cent. in excess of the above requirements (see Clause No. 15), all details of these members being correspondingly strengthened. Short floor-beam hangers will be required to have 50 per cent. excess of strength. **Section of Hip Verticals and Hangers.**

18. The same limiting unit stresses shall also be used for members strained by wind pressure or momentum of moving train, the stress increment being neglected in these cases. **Unit Stresses for Wind Bracing.**

Treatment of Stress Due to Centrifugal Force.

19. The stress due to centrifugal force shall be regarded as live load, and, when necessary, additions shall be made to the sections of truss chords or girder flanges until the unit stress does not exceed 17,000 pounds in tension nor 17,000 pounds, properly reduced, in compression.

In lateral bracing the stress due to centrifugal force shall be increased 50 per cent. and the unit stresses provided for in Clause 18 shall be used.

In the case of deck structures, when the curvature exceeds six degrees, the lower lateral bracing shall be designed to carry half the stress due to centrifugal force, and properly designed sway bracing shall be introduced to transfer the stress from the upper to the lower system.

Limiting Value of $\frac{l}{r}$.

20. No compression member shall have a length exceeding 100 times its least radius of gyration, excepting wind bracing, in which the length may be 120 times the least radius of gyration.

Increase of Section Required by Wind Stress, &c.

21. In case the maximum stresses in chords of bridges, or posts of trestle towers, due to wind and momentum of train, added to the maximum stresses from vertical loading and centrifugal force, properly increased, shall exceed 19,000 pounds per square inch (properly reduced for buckling in the case of compression members), additions must be made to the sections until this limit is not exceeded.

Reversal of Stress.

22. Should the stresses be reversed in any possible case, proper allowance must be made for such reversal.

Bending Moment Due to Floor Loads on Top Chords.

23. When the floor system rests directly on a continuous top chord, the latter must be so proportioned that the algebraic sum of the stresses per square inch in the outer fibres, resulting from the direct compression, and three-fourths of the maximum bending moment (the chord being considered as a beam of one panel length, supported at the ends), shall not exceed the before-mentioned limiting stress in compression, the proper increment being added to each kind of loading. The bending moment at panel points shall be assumed equal but opposite in direction to that at mid-panel.

General Treatment of Secondary Stresses Due to Bending.

24. All other members which are subjected to bending moment in addition to direct stress are to be similarly treated.

25. To insure the stability of bridges under increased live loads, a live load shall be assumed 100 per cent. greater than that previously provided for in this specification. If the resultant stress, M (1+k), produces a stress per square inch in any member more than twice the permissible unit stress previously specified, additions must be made to the sections until that limit is not exceeded. Counters, having in no case less than one and one-half square inches of section, must be provided where required by the increased live load; and in case of reversal of stress the member must be properly designed to resist such reversal. **Stability Under Increased Live Loads.**

26. Pins and bolts are to be so proportioned that the maximum stress in the extreme fibres due to bending moment shall not exceed 22,000 pounds per square inch for soft steel, nor 25,000 pounds per square inch for pin steel, the centres of bearings of the members connected by the pin or bolt being taken as points of application of bending strains. **Bending Moment in Pins and Bolts.**

27. The bearing pressure of pins, bolts or rivets upon the projected semi-intrados (diameter x thickness) of the hole, shall not exceed 26,000 pounds per square inch for rivets, nor 22,000 pounds per square inch for pins and bolts. **Bearing Pressures, Pins and Rivets.**

28. The shearing stress per square inch of section on rivets, bolts or pins shall not exceed 11,000 pounds for soft steel, nor 12,000 pounds for pin steel. **Shear in Rivets, Pins and Bolts.**

29. Net sections must be used in all cases in proportioning tension members, and in deducting rivet holes they shall be taken ⅛ of an inch larger in diameter than the nominal size of the rivets. **Net Sections. Tension Members.**

30. In the field-riveted connections of track stringers and floor beams, the number of rivets determined by the foregoing rules must be increased 33 1-3 per cent. in all cases. In all other field-riveted joints a 25 per cent. excess of rivets will be required if hand driven and a 10 per cent. excess if satisfactory power riveters are used. **Field-Riveted Connections.**

31. Rivets with countersunk heads shall be assumed to have three-fourths the value of corresponding rivets with full heads. **Value of Countersunk Rivets.**

32. Riveted tension members shall have a section through the pin-hole 25 per cent. in excess of the net section of the body of the member. The **Riveted Tension Members and Section at Pin-Holes.**

section back of the pin-hole shall be at least 75 per cent. of the section through the pin-hole.

Same Gross Section in Both Flanges of Plate Girders

33. No allowance shall in general be made for the web as resisting any of the bending moment in plate girders. The compression flange shall have the same gross sectional area as the tension flange. The unsupported length of the compression flange shall not exceed twelve times its width.

Shear in Web Rivets. Plate Girders.

34. In calculating the shearing stresses and bearing stresses in the web rivets of plate girders, the whole of the shear, with its proper increment, acting on the side of the panel next the abutment is to be considered as transferred into the flange angles in a distance equal to the depth of the girder.

Extra Rivets. Top Flanges of Plate Girders.

35. In the case of the rivets connecting the upper flange angles with the web in deck girders carrying the floor directly on the top flanges, allowance must be made for the concentrated load of a 12½ ton driver, which shall be considered as distributed over three ties.

Thickness of Web Plates.

36. The thickness of web plates shall be such that the maximum calculated shear, with its proper increment, shall not cause the shearing stress per square inch of net section of the web to exceed 13,000 pounds; but no web plate shall be less than ⅜ of an inch in thickness.

Rolled Beams and Channels as Girders.

37. Rolled beams and channels subjected to bending stresses shall be so proportioned that the stress per square inch in the outer fibers, deduced from the calculated bending moment (with its proper increment) and the moment of inertia of the section, shall not be more than 14,000 pounds. The unsupported length of the top flanges of such beams and channels shall in no case be greater than twelve times the flange width.

Minimum Sections.

38. For main members and their connections no material shall be used of less thickness than ⅜ of an inch; and for laterals and their connections no material shall be used of less thickness than 5-16 of an inch. Material of less thickness will be permitted only for lining or filling vacant spaces.

No material used in compression shall have an unsupported width of more than fifty times its thickness.

No lateral or sway rod shall be used having less than one square inch of section.

## SECTION 4.—DETAILS OF CONSTRUCTION.

### *A.—Wooden Floor System.*

**Cross-Ties.**

39. Cross-ties shall be of white oak spaced not more than six inches apart in the clear; and, in the case of all deck and half-through girder spans, and of through truss spans having steel floor stringers, the size of ties and all details of floor construction shall be as shown on standard plans.

**Wooden Floor Beams on Deck Trusses**

40. In the case of deck bridges with wooden floor beams, when the distance between centres of trusses, exceeds 6 feet, the floor beams shall be proportioned for a bending moment produced by the weight of a pair of 25,000 pound drivers distributed equally over three floor beams, the extreme fibre stress in the floor beams not exceeding 1000 pounds per square inch.

**Elevation of Rail on Curves.**

41. When the track is curved the outer rail is to be elevated as may be required, by cutting the cross-ties or floor beams with the proper bevel.

**Wooden Guard Rails.**

42. Guard rails of long-leaved southern pine or white pine, 6 by 8 inches in size, are to be placed outside of each track rail as shown on the standard floor plans; to be notched $1\frac{1}{2}$ inches over the cross-ties, and bolted down at every fourth tie and at splices with $\frac{3}{4}$-inch bolts. The guard rails are to be spliced over ties with half-and-half joints of 6 inches lap.

### *B.—General Details of Metal Work.*

**Adjustable Members.**

43. Adjustable members shall preferably be avoided, except in the case of counters of truss bridges.

**Portal Bracing.**

44. All through spans shall have portals at each end, connected rigidly to end posts. They shall be as deep as the specified head room will allow, and provision shall be made in the end posts to resist the bending strain produced by the wind pressure.

**Sway Bracing.**

45. Deck bridges shall have diagonal sway bracing at each panel, of sufficient strength to carry half the maximum stress increment due to wind and centrifugal force.

**Knee Braces.**

46. Pony trusses and half-through girders shall be provided with knee braces or gussets at

each floor beam or strut, and at the end if practicable.

Expansion Rollers. 47. All bridges 80 feet or more in length shall have at one end nests of turned friction rollers running between planed surfaces. Rollers shall be not less than 3 inches in diameter, and the pressure per lineal inch of roller, including the proper increment, shall not exceed $1200\sqrt{d}$ ($d =$ diameter of rollers in inches).

Sliding Bearings. 48. Bridges less than 80 feet in length shall be free to move at one end on planed surfaces.

Stiff Lower Chord and Hip-Verticals. 49. Single track bridges shall have the lower chord end panels stiffened, whether the end posts are vertical or inclined; and all through spans shall have stiff hip-verticals.

Assumed Temperature Variation. 50. Provision shall be made for a free expansion and contraction of the completed structure corresponding to a variation of temperature of 150 degrees Fahrenheit.

Pressure on Masonry. 51. Bed plates shall be so proportioned that the pressure upon masonry, including the proper increment, shall not exceed 400 pounds per square inch.

Symmetrical Sections. 52. All sections shall preferably be made symmetrical and the pins placed in the line of the neutral axis.

Camber. 53. All truss bridges with parallel chords shall be cambered by making the top chord longer than the bottom chord, in the proportion of $\frac{1}{8}$ inch for each 10 feet of length.

Connections for Wind Bracing. 54. In every case the connections between the wind bracing and the chords must be of greater strength than the wind bracing itself, and so designed as to avoid as far as possible inducing bending moments in any members of the structure; and such connections must be capable of transferring the longitudinal components of the wind stresses into the main truss chords in a direct and satisfactory manner, or a separate chord must be used for the lateral system.

### *C.—Riveted Work.*

Web Splices. Plate Girders. 55. Web plates of girders must be spliced at all joints with a plate on each side of the web, capable of transmitting the full shearing stress through the splice rivets.

**Rivet Spacing. Compression Members.**

56. In members subject to compression, rivets shall be so spaced that they shall not be farther apart in the direction of the stress than 16 times the thickness of the thinnest external plate connected, and not more than 50 times that thickness at right angles to the direction of stress.

**Rivet Pitch at Ends of Compression Members.**

57. At the ends of compression members the pitch shall not exceed 4 diameters of the rivet, for a distance equal to twice the greatest width of the member.

**Splices.**

58. All joints in riveted work, whether in tension or compression members, must be fully spliced.

**Limiting Pitch of Rivets, Distance from Edge of Plate, &c.**

59. The distance from the edge of any piece to the centre af a rivet hole must be not less than $1\frac{1}{2}$ times the diameter of the rivet, nor exceed 8 times the thickness of the plate; and the distance between centres of rivet holes shall not be less than 3 diameters of the rivet.

**Tie-Plates.**

60. All segments of compression members connected by lacing only shall have tie plates placed as near the ends as practicable. The tie plates shall have a length not less than the greatest width of the member, and a thickness not less than one-fortieth of the distance between the lines of connecting rivets, measured at right angles to the length of the member.

**Lattice Bars.**

61. Single lattice bars shall have a thickness of not less than 1-40 and double bars connected by a rivet at the intersection of not less than 1-60 of the distance between their rivets connecting them to the member; and their width shall be:—

| | |
|---|---|
| For 15-inch channels, or built sections with $3\frac{1}{2}$- or 4-inch angles. . . . . . . . . . . . . | $2\frac{1}{2}$ inches ($\frac{7}{8}$-inch rivets). |
| For 12- and 10-inch channels, or built sections with 3-inch angles . . . . . . . . . . . . . . . . | $2\frac{1}{4}$ inches ($\frac{3}{4}$-inch rivets.) |
| For 9- and 8-inch channels, or built sections with $2\frac{1}{2}$-inch angles . . . . . . . . . . . . | 2 inches ($\frac{5}{8}$-inch rivets.) |

The distance between connections of the lattice bars shall not exceed 8 times the least width of the segments connected.

**Pin Plates.**

62. All pin-holes shall be reinforced with additional material when necessary, so that the permissible pressure on pins shall not be exceeded. These

reinforcing plates must contain enough rivets to transfer the proportion of pressure which comes upon them in accordance with the previously stated rules for proportioning rivets.

Wide Girder Flanges Requiring 4 Rows of Rivets.

63. Flanges of plate girders running over 14 inches in width, or projecting more than 3 inches beyond the edge of flange angles, shall have at least four lines of rivets.

Length of Cover Plates. Plate Girders.

64. In all plate girders having cover plates, at least one plate on each flange shall extend from end to end of the same, and, in general, cover plates shall be made of such lengths as to allow of at least two rows of rivets of the regular pitch being placed at each end of the plate, in addition to those theoretically required.

Webb Stiffeners. Plate Girders.

65. The webs of plate girders shall have stiffeners riveted on both sides, with a close bearing against upper and lower flange angles, at the ends and inner edges of bearing plates, and at all points of local and concentrated loads; and also when the thickness of web is less than 1-60 of the unsupported distance between flange angles, at points throughout the length of the girder, generally not farther apart than the depth of the full web plate, with a maximum limit of 5 feet.

## SECTION 5.—MATERIALS.

### *A.—Rolled Steel.*

Character of Rolled Steel.

1. In general, soft steel will be used in all parts of the work. For pins, lateral bolts and expansion rollers, however, medium steel will be used. All steel must be made by the open-hearth process, and may be either basic or acid, at the discretion of the Chief Engineer.

Phosphorus Limit. Acid, Open-Hearth Steel.

2. If made in an acid furnace, the maximum allowable amount of phosphorus in the finished product shall be six-hundredths of one per cent.

Phosphorus Limit. Basic Open-Hearth Steel.

3. If made in a basic furnace, the maximum allowable amount of phosphorus in the finished product shall be four-hundredths of one per cent.

Surface Requirements.

4. The finished product shall be perfect in all parts and free from irregularities and surface imperfections of all kinds. All steel must be free from piping.

5. No difference of more than two and one-half per cent. from the section shown on the plans will be permitted, except in the case of extra wide plates. Permissible Excess of Weight.

6. Every finished plate, bar or angle shall be plainly stamped on one side, near the middle, with a number identifying the melt. Steel for pins shall have the melt numbers stamped on the end. Rivet steel and small pieces, not forming part of the calculated section of members, may be shipped in bundles wired together, with the melt number on a metal tag attached. Marking Finished Pieces.

## *B.—Cast Steel.*

7. Cast steel shall be made in an open-hearth furnace, and shall fulfill the following requirements: Cast Steel. General.

(*a*) All steel castings shall be annealed. Annealing of Steel Castings.

(*b*) Every steel casting shall be made with a coupon for testing, which coupon shall be cut off after annealing, and the test shall be made from a ¾-inch round cut from the coupon. The test piece shall show an ultimate strength of at least 65,000 pounds, an elastic limit of not less than 33,000 pounds, an elongation of at least 15 per cent. in two inches, and a reduction of area of 20 per cent. at the point of fracture. Tests of Steel Castings.

(*c*) When the bearing surface of any steel casting is finished, there shall be no blow-hole visible exceeding one inch in either dimension, nor exceeding one-half a square inch in area. The length of blow-holes cut by any straight line laid in any direction shall never exceed one inch in any one foot. Soundness of Steel Castings.

## *C.—General Tests.*

8. A sample bar not more than two inches wide, and having a sectional area of not less than one-half a square inch, shall be cut from the finished product of every melt. When taken from metal more than two inches thick, the sample may be a turned, round bar. The laboratory tests shall be made on this sample bar in its natural state, without annealing. Sample Bar.

9. When a melt is rolled into several varieties of material, each variety shall be separately tested. A variety shall consist of one of the following shapes: Sheared Plates, Universal Mill Plates, Varieties of Material to be tested.

Beams, Angles, Channels, Z Bars, Flats, Rounds, Pin Steel, Eye-bar Steel.

Measured Length of 8 Inches for Elongation Test.

10. In the laboratory tests, measurements to determine elongation shall be made on an original length of eight inches.

Bending Test.

11. A piece of each sample bar shall be bent cold 180 degrees, and closed up against itself. In the case of "pin steel" the test shall be considered satisfactory if no crack nor flaw appear on the outside of the bent portion until the diameter of the circle around which the specimen is bent has become less than the thickness of the sample bar. Samples of "soft steel" will be further required to close upon themselves without developing any crack or flaw on the outside of the bent portion before the test shall be considered satisfactory.

Drifting Test

12. The ductility of the metal must be such that a punched hole ⅞ inch in diameter, the center of which is not more than one and one-half inches from the sheared or rolled edge of the piece, may be enlarged by drifting to a diameter 50 per cent. greater than the original hole without cracking the specimen at any point.

Ultimate Strength, Elastic Limit, &c

13. The sample bar shall be tested in a lever machine, and shall fulfill the following requirements:

| | Ultimate Strength. | Elastic Limit. | Elongation. | Reduction of Area |
|---|---|---|---|---|
| Pin Steel .. .. | 62,000 to 70,000 lbs | 33,000 lbs | 17 per ct | 40 per ct |
| Soft Steel . . | 52,000 to 62,000 lbs | 28,000 lbs | 25 per ct | 50 per ct. |
| Rivet Steel..... | 48,000 to 56,000 lbs. | 28,000 lbs. | 28 per ct. | 56 per ct. |

Fracture.

14. The entire fracture shall be silky.

Minimum Limits.

15. The requirements for Elastic Limit,. Elongation and Reduction of Area are minima, and no steel will be accepted which fails to meet these requirements, except as provided in Clause 16.

Duplicate Tests, When Allowed.

16. Duplicate tests may be made when the sample tested fulfills five or the six requirements. If the second test and also the average of both tests meet all the requirements the melt may be accepted.

Chemical Analyses.

17. Analyses shall be made showing the amount of phosphorus, carbon, sulphur, silicon and manganese whenever required, the drillings for these analyses being taken directly from the finished material.

### *D.—Full-Sized Eye-bar Tests.*

18. The eye-bars required for full-sized tests and those required for the structure shall be made at one time, The test bars shall be selected by the inspector and must be fair average specimens of those which would be classed as good bars, acceptable for the work. No bar which is known to be defective in any way shall be selected for testing. **Selection of Eye-Bars for Test.**

19. The test bars shall show an elastic limit of not less than 27,000 pounds and an ultimate strength of not less than 48,000 pounds per square inch of section. **Elastic Limit and Ultimate Strength of Test Bars.**

20. The test bars will be required to develop an average stretch of 16 per cent. and a minimum stretch of 14 per cent. before breaking. The elongation to be measured on a gauged length of 10 feet, including the fracture. **Elongation of Test Bars.**

21. The specified elongations are minima, and a failure in these requirements will be sufficient cause for condemning the bars represented by the test. **Minimum Limit of Elongation.**

22. In general, bars will be required to break in the body. When a bar breaks in the head, but develops 14 per cent. elongation before breaking, a second bar shall be selected from the same lot. If this bar breaks in the body and the average elongation of the two bars is not less than 16 per cent., the bars of this lot may be accepted. **Location of Fractures.**

23. If more than one-third of all the bars tested break in the head, this shall be deemed sufficient cause for the rejection of the entire bill of eye-bars. **Condemnation if Bars Break in Head.**

## SECTION 6.—WORKMANSHIP.

24. All workmanship must be of the best kind now in use. Where there is any uncertainty as to the quality of the work required by the plans or specifications, it shall be the duty of the inspector to require the best class of work which any interpretation would admit of. **Quality of Workmanship in General.**

25. All plates, angles and shapes shall, when necessary, be carefully straightened at the shop before assembling. **Straightening Material.**

26. The nominal size of rivets shown on the plans shall be understood to be the actual size of the cold rivet before heating. **Size of Rivets.**

**Rivet Hole 1-16 Inch Larger than Cold Rivet.**

27. The diameter of the finished rivet hole shall be not more than one-sixteenth of an inch greater than the diameter of the cold rivet, and shall always be of such size that the hot rivet shall not drop freely into the hole, but shall require a slight pressure to force it in.

**Reaming all Holes When Material Exceeds 5-8 Inch in Thickness**

28. Soft steel up to a thickness of $\frac{5}{8}$ inch may be punched without subsequent reaming. Soft steel of greater thickness than $\frac{5}{8}$ inch must be punched with holes $\frac{1}{8}$ inch less in diameter than the size of the rivets shown on the drawings, and the holes then reamed to the proper size.

**Reaming Must be Done After Assembling.**

29. All reaming of rivet holes must be done after the various pieces have been punched and assembled. After reaming, every hole shall be entirely smooth, showing that the reaming tool has everywhere touched the metal.

**Cleaning and Painting Contact Surfaces**

30. Before assembling, the several pieces shall be cleaned. The surfaces in contact shall then be painted with one heavy coat of red-lead paint, and the parts assembled while the paint is fresh, and then reamed and riveted up.

**Abutting Surfaces to be Faced.**

31. All abutting surfaces of compression members (except the flanges of plate girders) shall be carefully faced so as to have even bearings after they are riveted up complete. Abutting members fitted with splice plates must be brought into close and forcible contact, and the rivet holes reamed in position before leaving the works; the splice plates being marked so as to go in the same position in erecting.

**Compression Members to be Straight.**

32. Compression members must be straight and free from kinks or buckles in the finished piece.

**Facing Bearing Surfaces**

33. All bearing surfaces shall be truly faced.

**Web Stiffeners to Bear.**

34. The web stiffeners of plate girders shall in all cases have a close bearing against the flange angles.

**Flange Angles of Stringers Must be Square and Straight.**

35. The flange angles of stringers must be square and straight. The outside edges of the top angles carrying the cross-ties must never be above a true plane, and not more than 1-16 inch below a true plane coincident with the roots of the angles.

**Finishing Ends of Stringers and Floor Beams.**

36. The ends of all stringers and floor beams shall be squared in a facer. The header angles of stringers and floor beams shall be perfectly square and so accurately fitted that when the ends of the stringers and floor beams are faced to the figured length, the amount of metal removed shall not reduce

the thickness at the roots of the header angles by more than 1-16 inch while securing a true surface for the whole width of the connection.

37. In all fields connections, except for lateral and sway bracing, the various parts to be riveted together shall be assembled in the shop, and all open holes shall be reamed out while the parts are so assembled; or an iron templet at least one inch thick shall be made and all parts reamed to fit this templet. **Field Connections to be Shop-Fitted.**

38. All rivets, whether driven by power or bv hand, shall be regular in shape, with hemispherical heads (conformable in shape and size to the standard templets of the Pennsylvania Railroad Company) concentric with the axes, absolutely tight, and shall completely fill the holes. Tightening by caulking or recupping will not be allowed. **Shape of Rivet-Heads, &c.**

39. After the working is completed, eye-bars shall be annealed in a suitable annealing furnace by heating them to a uniform dark-red heat and allowing them to cool slowly. **Annealing Eye-Bars.**

40. The thickness of the heads of eye-bars shall not be more than 1-16 inch greater than the thickness of the bar; the form of the heads to be determined by the dies in use at the works where the bars are made, provided that the heads shall be of sufficient strength to break the body of the bar. **Heads of Eye-Bars.**

41. Eye-bars shall be bored truly and at exact distances; the pin-holes to be in the axis of the bar and exactly at right angles to the planes of the flat surfaces. **Boring Eyes in Eye-Bars.**

42. When all the bars of the same panel are piled together, it shall be possible to pass the pins through both pin-holes at the same time without driving. Every bar shall be tested for this requirement. **Test for Length of Eye-Bars.**

43. Pins up to 7 inches in diameter shall be rolled. **Pins to be Rolled.**

44. All pin-holes in riveted members shall be bored or drilled after all other work is completed. They shall be bored parallel with each other and at right angles to the axis of the member, and no variation of more than 1-32 inch will be allowed in the length between centres of pin-holes. **Pin-Holes in Riveted Members.**

45. All pin-holes shall be bored with a sharp tool making a clean, smooth cut. Roughness in pin-holes will be sufficient reason for rejecting a whole member. **Smoothness of Finish. Pin-Holes.**

Play in Pin-Holes.

46. All pin-holes shall be bored to fit the pins with a play not exceeding 1-32 inch.

Shop Measurement Between Pin-Holes.

47. Shop measurements shall be made between the bearing edges of tension or compression members, with a proper allowance for the diameter of the pin. An iron standard of the same temperature as the piece measured shall always be used.

Finished Size of Pins.

48. All pins shall be accurately turned to a gauge, and shall be of full size throughout.

Cleaning and Oiling all Material Before Shipment.

49. In general, all material shall be cleaned, and if necessary scraped, and given one coat of boiled linseed oil after inspection and before shipment.

Painting Inaccessible Surfaces.

50. All inaccessible surfaces shall be given one heavy coat of red lead in raw linseed oil before shipment.

Treatment of Machined Surfaces.

51. All machined surfaces shall be cleaned, oiled and given a heavy coat of white lead and tallow after inspection and before shipment.

Specifications Binding on Sub-Contractors.

52. Sub-contractors are fully bound by these specifications in every respect, and free access and information is to be given by them for thorough inspection of material and workmanship, and all required test pieces, etc., properly shaped, are to be provided, as may be requested, without charge. All shipments of material not properly inspected and passed are at the risk of the principal contractor.

Use Figured Dimensions. No Alterations Unless Authorized.

53. In all cases, figured dimensions on drawings are to be taken in preference to any measurements by scale, and no alterations are to be made unless authorized in writing by the Chief Engineer or the Engineer of Bridges.

*General Clauses.*

Proposal.

1. Bidders shall submit sealed proposals in conformity with the terms named in the letter of invitation. When so required the proposal shall be accompanied by a strain sheet, with full information as to calculated stresses and sizes of all material.

Indemnity from Patent Suits

2. The contractor shall bear the cost of any suit which may arise, and shall pay all damages which may be awarded in consequence of the use by said contractor of any patented device in the construction of any bridge or other work under these specifications and for the use of the Pennsylvania Railroad Company.

3. Immediately after the award of a contract for bridge or other structural work, a complete set of drawings in detail, including the strain sheet above mentioned, shall be furnished by the contractor; the drawings to be made on the dull side of tracing linen and the size of each drawing to be 24 inches by 36 inches. Blue prints of these drawings shall be submitted to the Chief Engineer of the railroad company for his approval before work is begun in the shop. **Detail Drawings.**

After approval of the drawings the contractor shall furnish the Chief Engineer with 3 sets of prints for temporary use during the progress of the work, and upon completion of the work the original tracings shall be permanently filed in the office of said Chief Engineer.

WM. H. BROWN,
*Chief Engineer.*

WM. A. PRATT,
*Engineer of Bridges.*
January 1, 1901.

TABLE A.

LIVE LOADS—SPANS FROM 5 TO 110 FEET.

| Spans in feet. | Moments. 1 Rail. Foot-pounds. | Shears. 1 Rail. Pounds. | Cross-girder Reactions. 1 Rail Pounds. | Equivalent Uniform Loads in Pounds per foot of Track. | | |
|---|---|---|---|---|---|---|
| | | | | Moments. | Shears. | Cross-girder Reactions. |
| 5 | 31300 | 25000 | 25000 | 20000 | 20000 | 10000 |
| 6 | 37500 | 25000 | 25700 | 16670 | 16670 | 8570 |
| 7 | 43800 | 26700 | 31400 | 14280 | 15260 | 8970 |
| 8 | 50000 | 28900 | 35800 | 12500 | 14450 | 8950 |
| 9 | 56300 | 30600 | 39100 | 11110 | 13600 | 8800 |
| 10 | 62500 | 32500 | 41800 | 10000 | 13000 | 8360 |
| 11 | 68800 | 34100 | 44000 | 9090 | 12400 | 8000 |
| 12 | 78400 | 35800 | 47700 | 8710 | 11930 | 7950 |
| 13 | 93500 | 38100 | 50800 | 8850 | 11720 | 7820 |
| 14 | 110000 | 40100 | 53400 | 8980 | 11460 | 7630 |
| 15 | 126500 | 41800 | 56400 | 9000 | 11150 | 7520 |
| 16 | 143000 | 43300 | 59100 | 8940 | 10830 | 7390 |
| 17 | 159500 | 45300 | 61400 | 8830 | 10660 | 7220 |
| 18 | 176000 | 47700 | 63400 | 8690 | 10600 | 7040 |
| 19 | 192500 | 49800 | 65300 | 8530 | 10480 | 6870 |
| 20 | 209000 | 51700 | 66900 | 8360 | 10340 | 6690 |
| 21 | 227900 | 53400 | 68500 | 8270 | 10170 | 6520 |
| 22 | 249600 | 55000 | 69800 | 8250 | 10000 | 6350 |
| 23 | 271200 | 56400 | 71500 | 8200 | 9810 | 6220 |
| 24 | 292900 | 57800 | 73200 | 8140 | 9630 | 6100 |
| 25 | 314700 | 59000 | 75500 | 8060 | 9440 | 6040 |
| 26 | 336400 | 60500 | 77500 | 7960 | 9310 | 5960 |
| 27 | 358200 | 61900 | 79400 | 7860 | 9170 | 5880 |
| 28 | 379900 | 63200 | 81100 | 7750 | 9030 | 5790 |
| 29 | 401700 | 64400 | 83000 | 7640 | 8880 | 5720 |
| 30 | 424000 | 65500 | 85000 | 7540 | 8730 | 5670 |
| 32 | 473200 | 67600 | 89600 | 7390 | 8450 | 5600 |
| 34 | 522400 | 69400 | 93600 | 7230 | 8170 | 5510 |
| 36 | 571600 | 71900 | 97900 | 7060 | 7990 | 5440 |
| 38 | 620900 | 74100 | 102700 | 6880 | 7800 | 5410 |
| 40 | 670100 | 76200 | 107000 | 6700 | 7620 | 5350 |
| 42 | 719300 | 78700 | 111500 | 6520 | 7500 | 5310 |
| 44 | 768500 | 81000 | 116000 | 6350 | 7360 | 5270 |
| 46 | 819700 | 83000 | 120400 | 6200 | 7220 | 5230 |
| 48 | 876000 | 85600 | 125200 | 6080 | 7130 | 5220 |
| 50 | 938700 | 87900 | 129800 | 6010 | 7030 | 5190 |
| 55 | 1099300 | 93900 | ........ | 5810 | 6830 | ........ |
| 60 | 1277300 | 99300 | ........ | 5680 | 6620 | ........ |
| 65 | 1473000 | 104000 | ........ | 5580 | 6400 | ........ |
| 70 | 1677400 | 109500 | ........ | 5480 | 6260 | ........ |
| 75 | 1899200 | 115700 | ........ | 5400 | 6170 | ........ |
| 80 | 2137600 | 122300 | ........ | 5340 | 6120 | ........ |
| 85 | 2393000 | 129400 | ........ | 5300 | 6090 | ........ |
| 90 | 2666100 | 135900 | ........ | 5270 | 6040 | ........ |
| 95 | 2939200 | 142300 | ........ | 5210 | 5990 | ........ |
| 100 | 3214600 | 148100 | ........ | 5140 | 5920 | ........ |
| 105 | 3500600 | 153500 | ........ | 5080 | 5850 | ........ |
| 110 | 3800500 | 159700 | ........ | 5030 | 5810 | ........ |

TABLE B.

COEFFICIENTS OF STRESS INCREMENT.

Case 1.—Stresses of one kind only—all compression or all tension.

$$k = \frac{1-R}{1+R}$$

| R. | k. | R. | k. | R. | k. | R. | k. | R. | k. |
|---|---|---|---|---|---|---|---|---|---|
| 1.00 | .000 | 0 79 | .117 | 0.58 | .266 | 0 37 | .460 | 0.16 | .724 |
| .99 | .005 | .78 | .124 | .57 | .274 | .36 | .479 | .15 | .739 |
| .98 | .010 | .77 | .130 | .56 | .282 | .35 | .482 | .14 | .754 |
| .97 | .015 | .76 | .136 | .55 | .290 | .34 | .493 | .13 | .770 |
| .96 | .020 | .75 | .143 | .54 | .299 | .33 | .504 | .12 | .786 |
| 95 | .026 | .74 | .149 | .53 | .307 | .32 | .515 | .11 | .802 |
| .94 | .031 | 73 | .156 | .52 | .316 | .31 | .527 | .10 | .818 |
| .93 | .036 | .72 | .163 | .51 | .325 | .30 | .538 | .09 | .835 |
| .92 | .042 | .71 | .170 | .50 | .333 | .29 | .550 | .08 | .852 |
| .91 | .047 | 70 | .176 | .49 | .342 | .28 | 563 | .07 | 869 |
| .90 | .053 | .69 | .183 | .48 | .351 | .27 | .575 | 06 | .887 |
| .89 | .058 | .68 | .190 | .47 | .361 | .26 | .587 | .05 | .905 |
| .88 | .064 | .67 | .198 | 46 | .370 | .25 | 600 | .04 | .923 |
| .87 | .070 | .66 | .205 | .45 | .379 | .24 | .613 | .03 | .942 |
| .86 | .075 | .65 | .212 | .44 | .389 | .23 | .626 | .02 | .961 |
| .85 | .081 | .64 | .220 | .43 | .399 | .22 | .639 | .01 | .980 |
| .84 | .087 | .63 | .227 | .42 | .408 | .21 | .653 | .00 | 1.000 |
| .83 | 093 | .62 | .235 | .41 | .418 | .20 | .667 | | |
| .82 | .099 | .61 | .242 | .40 | .429 | .19 | .681 | | |
| .81 | .105 | .60 | 250 | .39 | .439 | .18 | .695 | | |
| .80 | .111 | .59 | .258 | .38 | .449 | .17 | .709 | | |

TABLE C.

COEFFICIENTS OF STRESS INCREMENT.

Case 2 —Stresses subject to reversal.

$$k=\frac{2+R}{2-R}$$

| R. | k. | R. | k. | R. | k. | R. | k. | R. | k. |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 1.000 | 0.21 | 1.235 | 0.42 | 1.532 | 0.63 | 1 920 | 0 84 | 2 448 |
| .01 | 1.010 | .22 | 1.247 | .43 | 1 548 | 64 | 1 941 | .85 | 2.478 |
| .02 | 1.020 | .23 | 1 260 | .44 | 1.564 | .65 | 1.963 | .86 | 2.509 |
| .03 | 1.030 | .24 | 1.273 | .45 | 1.581 | .66 | 1.985 | 87 | 2 540 |
| .04 | 1.041 | .25 | 1.286 | .46 | 1.597 | .67 | 2 007 | 88 | 2.571 |
| .05 | 1.051 | .26 | 1.299 | .47 | 1.614 | .68 | 2 030 | .89 | 2.603 |
| .06 | 1.062 | .27 | 1.312 | .48 | 1.632 | .69 | 2.053 | .90 | 2 636 |
| .07 | 1.073 | .28 | 1.325 | .49 | 1 649 | .70 | 2.077 | .91 | 2.670 |
| .08 | 1.083 | .29 | 1.339 | .50 | 1.667 | .71 | 2 101 | .92 | 2 704 |
| .09 | 1.094 | 30 | 1.353 | .51 | 1.685 | .72 | 2 125 | .93 | 2 738 |
| 10 | 1.105 | .31 | 1.367 | .52 | 1.703 | .73 | 2.150 | .94 | 2.773 |
| .11 | 1.116 | .32 | 1.381 | .53 | 1.721 | .74 | 2.175 | .95 | 2.809 |
| .12 | 1.128 | .33 | 1.395 | .54 | 1.740 | .75 | 2.200 | .96 | 2 846 |
| .13 | 1.139 | .34 | 1.409 | .55 | 1.759 | .76 | 2.226 | .97 | 2 884 |
| .14 | 1.150 | .35 | 1.424 | .56 | 1.778 | .77 | 2.252 | .98 | 2.922 |
| .15 | 1.162 | .36 | 1.439 | .57 | 1.797 | .78 | 2.279 | .99 | 2.960 |
| .16 | 1.174 | .37 | 1.454 | .58 | 1.817 | .79 | 2.306 | 1.00 | 3.000 |
| .17 | 1.186 | .38 | 1.469 | .59 | 1.837 | 80 | 2.333 | | |
| .18 | 1.198 | .39 | 1.484 | .60 | 1.857 | .81 | 2.361 | | |
| .19 | 1.210 | .40 | 1.500 | .61 | 1.878 | .82 | 2 390 | | |
| .20 | 1.222 | .41 | 1.516 | .62 | 1.899 | .83 | 2.419 | | |

TABLE D.

PERMISSIBLE COMPRESSIVE STRESSES.

l=length of piece; r=least radius of gyration (both in inches).

$$p = \frac{15{,}000}{1 + \frac{l^2}{13{,}500 r^2}}$$

| $\frac{l}{r}$ | p | $\frac{l}{r}$ | p | $\frac{l}{r}$ | p | $\frac{l}{r}$ | p |
|---|---|---|---|---|---|---|---|
| 10 | 14900 | 38 | 13550 | 66 | 11340 | 94 | 9070 |
| 12 | 14840 | 40 | 13410 | 68 | 11170 | 96 | 8910 |
| 14 | 14790 | 42 | 13270 | 70 | 11010 | 98 | 8760 |
| 16 | 14720 | 44 | 13120 | 72 | 10840 | 100 | 8620 |
| 18 | 14650 | 46 | 12970 | 74 | 10670 | 102 | 8470 |
| 20 | 14570 | 48 | 12820 | 76 | 10510 | 104 | 8330 |
| 22 | 14480 | 50 | 12660 | 78 | 10340 | 106 | 8190 |
| 24 | 14380 | 52 | 12500 | 80 | 10180 | 108 | 8050 |
| 26 | 14280 | 54 | 12340 | 82 | 10010 | 110 | 7910 |
| 28 | 14170 | 56 | 12170 | 84 | 9850 | 112 | 7780 |
| 30 | 14060 | 58 | 12010 | 86 | 9690 | 114 | 7640 |
| 32 | 13940 | 60 | 11840 | 88 | 9530 | 116 | 7510 |
| 34 | 13820 | 62 | 11670 | 90 | 9370 | 118 | 7380 |
| 36 | 13690 | 64 | 11510 | 92 | 9220 | 120 | 7260 |

## TABLE E.

### MAXIMUM BENDING MOMENTS IN PINS.

**With extreme Fibre Stresses of 22000 pounds per square inch for Soft Steel, and 25000 pounds per square inch for Medium Steel.**

| Diam. of Pin in Inches. | Area of Pin in Square Inches. | Moments in Inch-Pounds. 22000 lbs. per sq. in. | Moments in Inch-Pounds. 25000 lbs. per sq in. | Diam of Pin in Inches. | Area of Pin in Square Inches. | Moments in Inch-Pounds. 22000 lbs per sq in | Moments in Inch-Pounds. 25000 lbs. per sq in. |
|---|---|---|---|---|---|---|---|
| 2 | 3.142 | 17280 | 19600 | 6½ | 33.183 | 593100 | 674000 |
| 2⅛ | 3.547 | 20730 | 23600 | 6⅝ | 34.472 | 628000 | 713700 |
| 2¼ | 3.976 | 24600 | 28000 | 6¾ | 35.785 | 664200 | 754800 |
| 2⅜ | 4.430 | 28900 | 32900 | 6⅞ | 37.122 | 701800 | 797500 |
| 2½ | 4.909 | 33700 | 38400 | 7 | 38.485 | 740800 | 841900 |
| 2⅝ | 5.412 | 39000 | 44400 | 7⅛ | 39.871 | 781200 | 887800 |
| 2¾ | 5.940 | 44900 | 51000 | 7¼ | 41.282 | 823000 | 935300 |
| 2⅞ | 6.492 | 51300 | 58300 | 7⅜ | 42.718 | 866300 | 984500 |
| 3 | 7.069 | 58300 | 66300 | 7½ | 44.179 | 911200 | 1035400 |
| 3⅛ | 7.670 | 65900 | 74900 | 7⅝ | 45.664 | 957500 | 1088100 |
| 3¼ | 8.296 | 74100 | 84300 | 7¾ | 47.173 | 1005300 | 1142500 |
| 3⅜ | 8.946 | 83000 | 94400 | 7⅞ | 48.707 | 1054800 | 1198700 |
| 3½ | 9.621 | 92600 | 105200 | 8 | 50.265 | 1105800 | 1256600 |
| 3⅝ | 10.321 | 102900 | 116900 | 8⅛ | 51.849 | 1158500 | 1316500 |
| 3¾ | 11.045 | 113900 | 129400 | 8¼ | 53.456 | 1212800 | 1378200 |
| 3⅞ | 11.793 | 125600 | 142800 | 8⅜ | 55.088 | 1268800 | 1441800 |
| 4 | 12.566 | 138200 | 157100 | 8½ | 56.745 | 1326400 | 1507300 |
| 4⅛ | 13.364 | 151600 | 172300 | 8⅝ | 58.426 | 1385800 | 1574800 |
| 4¼ | 14.186 | 165800 | 188400 | 8¾ | 60.132 | 1446900 | 1644200 |
| 4⅜ | 15.033 | 180800 | 205500 | 8⅞ | 61.862 | 1509800 | 1715700 |
| 4½ | 15.904 | 196800 | 223700 | 9 | 63.617 | 1574500 | 1789200 |
| 4⅝ | 16.800 | 213700 | 242800 | 9⅛ | 65.397 | 1641100 | 1864800 |
| 4¾ | 17.721 | 231500 | 263000 | 9¼ | 67.201 | 1709400 | 1942500 |
| 4⅞ | 18.665 | 250200 | 284000 | 9⅜ | 69.029 | 1779600 | 2022300 |
| 5 | 19.635 | 270000 | 306800 | 9½ | 70.882 | 1851800 | 2104300 |
| 5⅛ | 20.629 | 290700 | 330400 | 9⅝ | 72.760 | 1925900 | 2188500 |
| 5¼ | 21.648 | 312500 | 355200 | 9¾ | 74.662 | 2001900 | 2274900 |
| 5⅜ | 22.691 | 335400 | 381100 | 9⅞ | 76.590 | 2079900 | 2363500 |
| 5½ | 23.758 | 359300 | 408300 | 10 | 78.54 | 2159900 | 2454400 |
| 5⅝ | 24.850 | 384400 | 436800 | 10¼ | 82.52 | 2325900 | 2643100 |
| 5¾ | 25.967 | 410600 | 466600 | 10½ | 86.59 | 2500200 | 2841200 |
| 5⅞ | 27.109 | 438000 | 497700 | 10¾ | 90.76 | 2683200 | 3049100 |
| 6 | 28.274 | 466500 | 530200 | 11 | 95.03 | 2874800 | 3266800 |
| 6⅛ | 29.465 | 496300 | 564000 | 11¼ | 99.40 | 3075400 | 3494800 |
| 6¼ | 30.680 | 527300 | 599200 | 11½ | 103.87 | 3284800 | 3732800 |
| 6⅜ | 31.919 | 559600 | 635900 | 12 | 113.10 | 3732200 | 4241200 |

TABLE F.

SHEARING AND BEARING VALUE OF RIVETS IN POUNDS.

| Diam. of Rivet Inches. | Area of Rivet in Square Inches. | Single Shear at 11000 lbs. per Square Inch. | Bearing Value for Different Thicknesses of Plate in Inches at 26000 Pounds per Square Inch. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ | 1 |
| $\frac{1}{2}$ | 0.1964 | 2160 | 4060 | 4870 | 5690 | 6500 | | | | | | | | |
| $\frac{5}{8}$ | 0.3068 | 3370 | 5080 | 6090 | 7110 | 8120 | 9140 | 10150 | | | | | | |
| $\frac{3}{4}$ | 0 4418 | 4860 | 6090 | 7310 | 8530 | 9750 | 10970 | 12190 | 13400 | 14620 | | | | |
| $\frac{7}{8}$ | 0.6013 | 6610 | 7110 | 8530 | 9950 | 11370 | 12800 | 14220 | 15640 | 17060 | 18480 | 19910 | | |
| 1 | 0.7854 | 8640 | 8120 | 9750 | 11370 | 13000 | 14620 | 16250 | 17870 | 19500 | 21120 | 22750 | 24370 | 26000 |

All Bearing Values above or to right of upper Zigzag Lines are greater than Double Shear.
Values below or to left of lower Zigzag Lines are less than Single Shear.

### TABLE G.

**CENTRIFUGAL FORCE FOR DIFFERENT SPANS AND DEGREES OF CURVATURE—ONE TRACK.**

Formula $C = 220\ D\ (1 + \frac{13}{S})$

C=Centrifugal force in pounds per lineal foot of track.
D=Degree of curvature.
S=Span in feet.
Coefficient 220 is reduced by 12 for each degree of curvature above 6 degrees

| Span in Feet. | 1-Degree Curve. | 2-Degree Curve. | 3-Degree Curve | 4-Degree Curve | 5-Degree Curve | 6-Degree Curve. | 7-Degree Curve | 8-Degree Curve. | 9 Degree Curve | 10-Degree Curve | 11-Degree Curve. | 12-Degree Curve |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 360 | 730 | 1090 | 1450 | 1820 | 2180 | 2400 | 2590 | 2730 | 2840 | 2900 | 2930 |
| 25 | 330 | 670 | 1000 | 1340 | 1670 | 2010 | 2210 | 2380 | 2520 | 2610 | 2680 | 2700 |
| 30 | 320 | 630 | 950 | 1260 | 1580 | 1890 | 2090 | 2250 | 2370 | 2470 | 2520 | 2550 |
| 40 | 300 | 580 | 880 | 1170 | 1460 | 1750 | 1930 | 2080 | 2190 | 2230 | 2330 | 2350 |
| 60 | 270 | 540 | 800 | 1070 | 1340 | 1610 | 1770 | 1910 | 2020 | 2090 | 2140 | 2160 |
| 100 | 250 | 500 | 750 | 1000 | 1240 | 1490 | 1650 | 1770 | 1870 | 1940 | 1990 | 2010 |
| 200 | 230 | 470 | 700 | 940 | 1170 | 1410 | 1550 | 1670 | 1760 | 1830 | 1870 | 1890 |
| 300 | 230 | 460 | 690 | 920 | 1150 | ..... | .... | ..... | ..... | ...... | .... | ..... |
| 500 | 230 | 450 | ... | . | ... | ... | ..... | ... | ... | .... | . | ... |

P. R. R.

**189. German Specifications for the Preservation of Railroad Cross-ties.** The following Specifications for the preservation of railroad cross-ties are in use on the imperial German railways. They are given with approval by Mr. O. Chanute, past President of the American Society of Civil Engineers, in a paper before that Society, Vol. XLV (1901). Two methods are here given, one for pine ties and another for beech and oak ties. They are followed by specifications for testing the impregnating materials.

**I. German Specifications for Impregnating Pine Railroad Cross-ties, with a Chloride of Zinc Solution with an Addition of Coal Tar Containing Carbolic Acid.**

The process of impregnating by chloride of zinc solution, with addition of coal-tar oil containing carbolic acid, is divided into three parts.

1. Steaming of the ties.
2. Production of a partial vacuum and admission of the impregnating fluid.
3. Compression (forcing in) of the impregnating fluid.

The ties are loaded on iron cars, which are pushed into the impregnating cylinder, this is closed air-tight, and they are exposed to the action of steam; steaming is continued for a longer or shorter period, according to the time of year and the condition of the ties. The admission of steam into the impregnating cylinder must be regulated in such manner, that an inside pressure of 1.5 atmospheres (22 lbs. per square inch) above air pressure is reached within 30 minutes. For dry ties it will suffice to maintain this pressure in the impregnating cylinder for 30 minutes longer, but for green ties it should be kept up for another hour. For dry ties, therefore, the steaming takes at least 1 hour, while for green ties at least 1½ hours are necessary. A gauge attached to the cylinder indicates existence of the specified pressure. The valve at the bottom of the cylinder must be opened on admitting the steam, in order that the air contained in it may be driven out, but should be closed when steam begins to blow out. This valve should be opened repeatedly, as fast as steam condenses; open it at least every half-hour to draw off the water, and for the last time just before exhausting the air. When steaming is finished, the steam remaining in the impregnating cylinder is allowed to escape.

After steam is discharged a partial vacuum is produced in the cylinder containing the ties, until the vacuum gauge shows at the least a column of mercury of 60 cm. (23.6 ins.);

this partial vacuum must be maintained for ten minutes. On expiration of this time, while continually preserving the partial vacuum, allow the impregnating fluid, which meanwhile has been prepared in a separate vessel and heated to at least 65 degrees Cent. (149 degrees Fahr.), to enter the impregnating cylinder, filling it entirely. To prepare the impregnating fluid, add while heating, 1 kgr. of coal-tar oil to every 15 kgr. (6 2-3 per cent.) of the solution of zinc chloride.

To insure as perfect a mixture of the solution of zinc chloride with the coal-tar oil as possible, an effective stirring apparatus, combined with injection of steam and air, must be applied.

Next, a pressure pump is used to exert an excess of seven atmospheres above air pressure. This pressure to be maintained for not less than 30 minutes; if necessary, continue it for a longer time, until the ties have absorbed a certain amount of impregnating fluid as specified hereafter. The impregnating fluid is then run off.

The chloride of zinc solution intended for impregnating must be as nearly as possible free from foreign substances, and there must be no free acid. An admixture of other metals, notably iron, can only be allowed in a very slight percentage and only if it cannot be avoided in the manufacture. The solution must have a strength of 3.5 degrees Beaume = 1.0244 specific gravity at a temperature of 15 degrees Cent. (59 degrees Fahr.). The solution contains 1.26 per cent. of metallic zinc.

The coal-tar oil used must not contain over 1 per cent. of oils that boil below 125 degrees Cent. (257 degrees Fahr.). It must be so little volatile that its boiling point lies mainly between 150 degrees and 400 degrees Cent. (302 degrees and 752 degrees Fahr.). In no case is it permissible to have more than 25 per cent. of its weight volatilized below 235 degrees Cent. (455 degrees Fahr.). It must contain at least 20 to 25 per cent. of acid substances (creosote or oils resembling carbolic acid) that are soluble in caustic lye of soda of 1.15 specific gravity. The coal-tar oil must be entirely liquid at + 15 degrees Cent. (59 degrees Fahr.), and as much as possible free from naphthaline, so that on evaporation (fractional distillation) produced in a glass vessel in groups of 50 degrees each, it shall leave a residue of not more than 5 per cent. of napthaline. Its specific gravity should not be less than 1.020 at a temperature of + 15 degrees Cent. (59 degrees Fahr.) and should not exceed 1.055. To remove such impurities from the impregnating fluid as are due to the process, suitable settling (clarifying) apparatus should be provided.

The Contractor is required to report where he obtains his

supplies of zinc-chloride solution and of coal-tar oil, intended for use, and to furnish samples of the same to the Supply Office of the Imperial Railways at Strassburg in Alsace before commencing to impregnate. He will be permitted to purchase the solution of zinc chloride and the carbolized oil of coal-tar only from such factories whose samples have been approved by the Management of the Railways. The Railway Management reserves the right to test the fluids used at any time.

It is specified that the average absorption of impregnating fluid contained in every charge of the cylinder shall be the following:

*A.* Absorption of 35 kgr. (77 lbs.) for each tie of the first class, length of 2.70 m. (8.85 ft.).

*B.* Absorption of 26 kgr. (57 lbs.) for each tie of the second class, length of 2.50 m. (8.2 ft.).

*C.* Absorption of 310 kgr. per cubic meter (19 lbs. per cubic foot[1]) for ties of other dimensions.

To determine the amount of impregnating fluid absorbed by the ties, the following method must be adopted:

Weigh all ties on a platform scale placed under roof immediately before steaming them, and again after impregnating when dripping has ceased. The difference in weights equals amount of impregnating fluid absorbed. A deduction of 15 pfennigs per 10 kgr. (16 cents per 100 lbs.) will be made for shortage shown by this weighing test. In case the shortage amounts to more than one-sixth of the absorption specified, the impregnation must be repeated. If, on the other hand, the weighing shows that the ties have absorbed more than the amount specified, a bonus of 15 pfennigs for every 10 kgr. (16 cents per 100 lbs.) will be paid for such increase, up to a maximum of 15 per cent.

**II. German Specifications for Impregnating Beech and Oak Railroad Cross-ties with Hot Coal Tar Oil Containing Carbolic Acid.** The work of impregnating with hot carbolized oil of coal-tar (*i. e.*, oil of coal-tar containing carbolic acid) must be divided into two parts.

1. Drying of the ties, *i. e.*, withdrawing water from them.
2. Introduction of oil of coal-tar under pressure.

The ties are run into the impregnating cylinder and this is closed air-tight. Next, a partial vacuum, equal to at least 60 cm. (23.6 ins.) column of mercury, is produced in the impregnating cylinder and maintained for 10 minutes, and thereupon, while keeping up the vacuum, the hot oil of coal-tar is

[1] 3.5 degrees *B.* corresponds to 2.62 per cent dry zinc chloride. Hence, 19 × 2.62 per cent amounts to 0.498 lb. of dry zinc chloride per cubic foot —O. C.

made to flow in until it rises to a level that will prevent sucking over by the air pumps. The flowing in of the coal-tar oil may be accomplished all at once or at intervals, according to the dryness of the ties. While thus filling up, and afterward, the coal-tar is heated up inside the cylinder to at least 105 degrees Cent. (221 degrees Fahr.), but not higher than 115 degrees Cent. (239 degrees Fahr.), by means of steam coils. This heating should be accomplished during a space of time of not less than 3 hours. When this temperature is reached in the impregnating cylinder, it must be kept up for another hour, either with or without the partial vacuum, as may be judged necessary, in order that the ties may absorb the specified amount of oil of coal-tar.

The impregnating cylinder is connected with a pipe condenser from the instant that filling with hot coal-tar oil commences, and all the aqueous vapors driven out of the ties are condensed in this, the water being carried to a tank. This receiver must have a water gauge from which one can read off the amount of water evaporated from the ties.

After the drying of the ties or the extraction of water from them is finished, the impregnating cylinder is filled completely and the pressure pump started, which must produce a pressure of at least 7 atmospheres. This pressure is to be maintained for at least 30 minutes in treating beech ties and 60 minutes for oak ties, unless it proves necessary to prolong the time to obtain the amount of absorption specified. The oil of coal-tar is then drawn off.

The coal-tar oil used must be heavy oil, derived from the distillation of coal-tar, of greenish black color, specific gravity of 1.045 to 1.100 at 15 degrees Cent. (59 degrees Fahr.), boiling point between 150 degrees and 400 degrees Cent. (302 degrees and 752 degrees Fahr.).

While making fractional distillation no oils must pass over below 150 degrees Cent. (302 degrees Fahr.) and not more than 25 per cent of the volume at temperature up to 235 degrees Cent. (455 degrees Fahr.).

The coal-tar oil must contain by volume at least 10 per cent. of carbolic acid and, at a temperature of 15 degrees Cent. (59 degrees Fahr.), must be free from naphthalene and show no sediment.

To determine percentage of carbolic acid apply agitation to the oils heated to 400 degrees Cent. (752 degrees Fahr.) with a caustic solution of soda having specific gravity of 1.15. The difference in volume of oil before and after agitation gives percentage of carbolic acid.

The Contractor is required to state source of supply for his coal-tar oil and to furnish samples to the Supply Office of

the Imperial Railways at Strassburg before he commences work of impregnation. The coal-tar oil can only be purchased from factories whose samples have been approved by the Railway Management. The Railway Management reserves the privilege of at any time testing the coal-tar oil used.

It is specified that the average absorption of coal-tar oil for every charge of the cylinder shall be:

*a.* For one railroad tie, 1st class, 2.70 m. (8.85 ft.) long, of oak wood, 11 kgr. (24 lbs.); of beech wood, 36 kgr. (79 lbs.).

*b.* For one railroad tie, 2d class, 2.50 m. (8.20 ft.) long, of oak wood, 8 kgr. (18.6 lbs.); of beech wood, 28 kgr. (61.6 lbs.).

*c.* For ties of other dimensions per cubic meter (35.3 cu. ft.), of oak wood, 100 kgr. (220 lbs.); of beech wood, 325 kgr. (715 lbs.).

To determine the amount of coal-tar oil absorbed by the ties, these are weighed before the impregnation and again after it, when dripping of oil has ceased, using a platform scale placed under a roof. The difference in weight is amount of coal-tar oil absorbed. Correct the weight of the ties before impregnation by deducting from it weight of water delivered by condenser to the tank and obtained from the vapors distilled while drying in hot coal-tar oil, as weight of ties is reduced to this extent by drying process. If on examination it is proved that absorption amounts to less than five-sixths of that specified, the impregnation must be repeated.

For every shortage in coal-tar oil shown by above test, a deduction of 50 pfennigs for 10 kgr. (54.5 cents per 100 lbs.) will be made, but, on the other hand, an increase in absorption will be paid for at the same rate, a maximum of 15 per cent. increase being the limit of such payment.

**III. General Conditions.** The Contractor is required to give eight days' notice to the Supply Office of the time of intended commencing to impregnate ties, in order that the office may send an official to supervise same. This official must be freely admitted at all times to the plant of the Contractor, and all desired information must be readily furnished him. The Contractor must furnish all necessary appliances, apparatus and labor to make tests without charge.

In case the Contractor does not supply his own ties, the parties furnishing them will be required to deliver f. o. b. cars at the station nearest to the impregnating works, provided they are shipped by rail; ties delivered by wagon or other convey-

ance will be delivered loaded at storage yards of the factory without charge.

The hauling of ties from the station to factory will be at the expense of the Contractor for impregnation. He has also to provide for unloading, piling and handling of ties as per regulations. The Contractor will be paid for this labor the amount of 8 pfennigs (1.92 cents) for each track tie and 4 pfennigs (0.96 cent) for each switch tie of 1 m. These prices cover the exepnse of labor and tools required in receiving green ties, as well as that of reloading rejected ties; payment for a tie to be made only once.

The contractor for impregnating is held liable for all damages and loss of ties that may occur from the time they are delivered to him at the railroad station, or at his works, as long as ties remain at his works. This liability includes losses by fire occurring at the impregnation works and by theft committed while ties remain there. The Contractor must pay the value of all missing ties or of such as become unserviceable previous to their return after impregnation, but is not liable for splitting. He is, however, required to furnish without charge all necessary S-hooks and bolts for drawing together the cracks occuring during storage, and has to drive or put these in according to the directions of the supervising official.

When ties are turned over to the Contractor for impregnation, they are already supplied with S-hooks needed to draw together all existing cracks. Each beech track tie is also fitted with two iron bolts running through it, about 10 cm. (4 ins.), from each end in the direction of its breadth. It is his duty, therefore, to supply, without charge, only such S-hooks and bolts as may be needed thereafter, and of the same kind, and to fasten them.

On receiving the green ties they must be piled at the factory in such a way that air will circulate freely around each one. Each pile only to have length and breadth equal to length of one tie, and must contain 100 ties. The lowest layer of ties must rest on solid supports, so that they will never touch the ground. Storage yards must be thoroughly drained and have ditches if needed. Open spaces are to be left between the piles, which spaces must measure 80 cm. (32 ins.) in one direction and have a width of 40 cm. (16 ins.). This piling of ties must be finished at the latest in 14 days from receipt of same. Date of piling to be plainly marked on each pile.

For delay in completing impregnation of ties beyond time fixed by contract, unless previous express and written permission of the Imperial General Management has been obtained, the latter will collect a penalty from Contractor for such

delay, amounting to 1 per cent of the Contract value of the unfinished impregnation per week of such delay.

The Railroad Management reserves the right to employ the Contractor for impregnation to adze surface of ties in places for bed-plates of rails, as well as to bore holes for fastenings, if such work becomes necessary. This work to be done by direction of supervising official and before impregnating.

Strassburg, February....1898.
Imperial General Management of
Railways in Alsace-Lorraine.

Acknowledged: The preceding contract of............
this day the.............1....

D . ........ ......
*Contractor.*

## IV. German Specifications for testing Chloride of Zinc and Tar Oil, used for Preserving Timber.

For the impregnation of timber there are at present two products in use; 1st, chloride of zinc; 2d, tar-oil.

*Testing of Chloride of Zinc.* The chloride of zinc for impregnating purposes will be manufactured as a concentrated solution, containing about 50 per cent. of anhydrous chloride of zinc. It is best to use such a strong solution for testing, and for that purpose, samples are to be taken directly from the shipping tank or carboy.

The zinc chloride solution used must be as free from impurities as possible, particularly from iron and free acid. Therefore, it is to be determined whether or not iron and acid are present.

*Test for Free Acid.* Twenty grammes (by weight) of the above strong zinc chloride solution are to be mixed with distilled water; the whole to amount to 100 cu. cm. (by measure), the mixture to be well shaken.

*a.*—There is no free acid present if the mixture, by shaking, becomes cloudy, and, particularly if after a short period of rest, flakes settle down, which will again dissolve to a clear fluid, upon the addition of a few drops of muriatic acid (H Cl.). No further test is then required.

*b.*—If, after shaking, the mixture remains clear, then an excess of acid is present, the amount of which can be determined by the following manipulation:

Take several reagent bottles and put in each 10 cu. cm. of the above-described mixture, then add to each bottle a measured successively increasing quantity of a solution of one-tenth normal soda. For example: Add to the first reagent bottle 0.1 cu. cm., to the second 0.2 cu. cm., to the third 0.4 cu. cm., and so

on. Shake well and observe in which bottle a remaining white flaky precipitation will settle. The proportion of soda which lies between the mixture where a precipitation is produced, and that where no precipitation is produced, exactly represents the quantity of free acid present in the solution. For example, the mixture in the bottle to which 0.2 cu. cm. of the soda solution was added, remains clear, while in the following reagent bottle, where 0.4 cu. cm. soda solution was added, a precipitation is produced; then, 0.3 cu. cm. soda solution is exactly the quantity corresponding to the free acid present in the chloride of zinc solution.

Should there be required for this test more than 0.4 cu. cm. of the one-tenth normal soda solution, then the percentage of free acid is too high in the chloride of zinc solution, and such solution must not be used for impregnation.

*Testing for Iron.* Take 10 cu. cm. from the above-described mixture of zinc chloride solution and distilled water, and add a few drops of concentrated nitric acid ($H N O_3$) and shake well. Divide this mixture into two equal parts. To one part, without diluting, add a quantity of ammonia ($N H_4 O H$) and shake well. If this mixture remains clear, no iron is present. Through the presence of iron in the mixture, more or less brown flakes will precipitate, corresponding to the amount of iron present. Should there precipitate in the mixture a quantity of gray-white (not brown) flakes, then not only iron, but also another impurity (nearly always magnesia) is present. In this latter case a more complete test has to be made, and, therefore, the zinc chloride solution must be sent to a chemist. But this case will happen very seldom.

The second part of the mixture of 10 cu. cm. to which nitric acid was added, should be diluted with distilled water, and 5 cu. cm. of a solution of 10 per cent. yellow prussiate of potash added, the whole to be well shaken. A very ample precipitation will be produced, which will look snow-white, or very light yellowish, if the zinc chloride solution is free from iron; but in the presence of iron it will look more or less blue, according to the amount of iron. If the precipitation shows a corn flower blue color, then the zinc chloride solution surely contains a high percentage of iron and must therefore be rejected.

To avoid, in testing, the weighing of the 20 grammes of the strong solution, the use is recommended of the easier method of measuring. First find the specific gravity, at 15 degrees Celsius, of the strong concentrated zinc chloride solution. The quotient of this specific gravity into 20 grammes shows the number of cubic centimeters which must be measured off and which represent exactly 20 grammes by weight.

For instance, the specific gravity of the strong zinc chloride solution is 1.6, then 1.6 divided into 20 grammes gives the number of cubic centimeters ($\frac{20}{1.6}=12.5$ cu. cm.) which have to be measured off to be used for testing as described before.

*Testing of Tar-Oil.* At a temperature of 20 degrees Celsius the tar-oil must be limpid, and to test it, shake the tar-oil well, pour a few drops on a folded filter paper, and observe whether after absorption there remain undissolved particles on top of the paper. If the amount of these is large, the tar oil must not be used for impregnation. To find the specific gravity, the tar-oil must be heated, or cooled off, to a temperature of 15 degrees Celsius; then drop slowly an hydrometer into the same, and read the number at the surface of the oil. This number indicates the specific gravity of the tar-oil at 15 degrees Celsius; small variations in temperature are of minor importance, and can be corrected closely enough by adding or subtracting 3 to the figure in the third place of the specific gravity for every 2 degrees variation from 15 degrees Celsius.

*Laboratory Distillation of the Tar-Oil.* By means of a funnel, 102 cu. cm. of tar-oil at about 15 degrees Celsius are to be filled into a retort, a thermometer is to be inserted, but in such a manner that the quicksilver ball shall be in or below the neck of the retort but shall not touch the oil, or will not be covered by the same. The retort must be heated slowly, until all the water, which is contained in nearly every tar-oil, is evaporated. Stronger heat can then be applied to the retort, but it must be so regulated that in one second two drops will distill over. The distilled product will be caught in a graduated glass cylinder, and the different quantities are to be read and noted which distill over from the oil (become volatile), within the various intervals of temperature, say to 125 degrees Celsius (150 degrees) from 150 degrees to 235 degrees, and again from 150 degrees to 355 degrees Celsius, and which are specified in the "Description of the Process, and Specifications" as to the composition and proportions of the impregnating fluid.

*Finding the Percentage of Carbolic Acid. (Acid Constituents of the Oil.)* The entire amount of the distilled tar-oil is to be mixed in a separating funnel with 50 cu. cm. of caustic soda of 1.15 specific gravity at 15 degrees Celsius, shaken well for about five minutes, after which let it stand and settle. The caustic soda absorbs the carbolic acid and precipitates; the stopcock of the funnel is to be opened and the precipitated caustic soda is caught in a 200-cu. cm. graduated glass cylinder. The same operation must also be repeated with 50 cu. cm. of fresh caustic soda, to make sure that all carbolic acid is extracted from the oil. The caustic soda of both manipulations is then

to be combined, about two tablespoonfuls of salt (Na Cl) added and this dissolved by means of stirring; the required quantity of concentrated muriatic acid (H Cl) added, and the combination again stirred up until well mixed. After cooling off the hot mixture, read the quantity of the separated carbolic acid in percentage of cubic centimeters, and add to this number ½ per cent. for the small amount of carbolic acid still remaining in the acid solution.

All the figures obtained are to be compared with those specified in the description of the composition and proportions of the impregnating fluids. Small differences should not be cause for rejection, as small variations in testing, resulting from barometric changes, cannot be avoided, and the result of the test is influenced by them. However, the figures obtained by the above-described tests are sufficiently close to judge of the quality of the impregnating fluids. It is not advisable that the tar-oil for testing be taken directly from the shipping-tank, but it is better to take the samples from the receptacle of the apparatus in the impregnating plant from which the mixing vessels, or the impregnating cylinder (in the impregnation with pure oil) will be supplied.

The Chief of the Operating Inspection 3.

(Signed.) SETTGAST.

BERLIN, June 14th, 1899.

**190. Filter Gravel and Sand.** The following specification for the character, size, and placing of gravel and sand in a large gravity water-filter is new and is likely to be useful as filtration plants are adopted for city water supplies. It was used in the Albany Water Filtration Plant.

Depth.

*Filter Gravel.* On the floor of the filters and surrounding the underdrains shall be placed gravel or broken stone having a maximum depth of one (1) foot. Instructions will be given by the Engineer as to the exact arrangement and positions of the various layers when the stone commences to be received upon the ground, but the arrangement will be approximately as follows:—The lower 7 inches shall consist of broken stone or gravel which will remain upon a screen with a mesh of 1 inch, and which has but very few stones over 2 inches in diameter. Above this shall be placed 2½ inches of broken stone or gravel which has passed a screen with a mesh of 1 inch, and which remains upon a screen with a clear mesh of ⅜ of an inch, and above this shall be placed 2½ inches of broken stone or gravel, which

Arrangement of Layers.

has passed a screen with a mesh of $\frac{3}{8}$ of an inch, and which is coarser than the ordinary sand, and entirely free from fine material. The exact depth of the various layers and the meshes of the various screens may be varied somewhat, and the Contractor will be allowed to make such reasonable changes as will allow the material to be handled economically and to the best advantage, but before making any changes he shall consult with the Engineer, and no change shall be allowed which will in any way interfere with the efficiency of the filter.

Gravel shall not be placed within 6 feet of the inlet or outlet chambers, nor within 2 feet of the outside or cross-walls, these spaces being reserved for filling with sand. Proximity to Walls.

In case the gravel used for the lower layers should contain any material so fine that pieces might enter the joints of the drain pipe, the Engineer may order coarser material to be selected from the gravel or broken stone and to be placed about the joints, the quantity of such material not to exceed 1 cubic foot per joint. Selected for Joints.

The gravel for all of the layers may be broken trap rock screened to the proper sizes, or gravel screened from sand and gravel banks of a sandy nature. Gravel screened from hard pan or clayey material *cannot* be sufficiently cleaned. The gravel shall not contain more than a very small amount of shale or limestone. The gravel shall be washed entirely free from fine material so that water passing through it or agitated in contact with it will remain substantially clean. No dirt or foreign matter of any kind shall be allowed to enter the filters after beginning to place the gravel and any gravel made dirty in any way after placing shall be at once removed and replaced to the satisfaction of the Engineer. Quality

(164) The price bid per cubic yard for filter gravel includes the screening, washing and placing of all of the different grades above enumerated, no deduction being made for the space occupied by the underdrains. Payment.

*Filter-Sand in Place.* The filter-sand shall be clean, river, beach or bank sand, with either sharp or rounded grains. It shall be entirely free from clay, dust or organic impurities, and shall, if necessary, be washed to remove such materials from it. Quality.

The grains shall, all of them, be of hard material which will not disintegrate and shall be of the following diameters:—Not more than one per cent., by weight, less than 0.13 of a millimeter nor more than ten per cent., less than 0.27 of a millimeter; at least ten per cent., by weight, shall be less than 0.36 of a millimeter, and at least seventy per cent., by weight, less than one millimeter, and no particles shall be more than five millimeters in diameter. The diameter of sand grains will be computed as the diameters of spheres of equal volumes. The sand shall not contain more than two per cent., by weight, of lime and magnesia taken together and calculated as carbonates. In all other respects the sand shall be of a quality satisfactory to the Engineer. The Contractor shall take adequate precaution to prevent foreign or polluting material from becoming mixed with the sand, and shall protect the sand from such material until the final acceptance of the work or until the filters are put in operation.

Samples Examined by Engineer. Samples of sand fulfilling the above requirements may be seen in the offices of the Engineer, and he will examine samples of sand submitted by intending bidders and advise them whether or not they are suitable.

Placing in Layers. The filter-sand shall be placed in the filters in four layers, each layer to be about one foot thick, and the sand shall not be dropped from a height into final position or otherwise unduly compacted. The three first layers may be filled in to only approximate depths and the surfaces need not be smoothed. The final layer shall be brought to a true and even grade, and the surface left smooth and uniform, and such allowance shall be made for settlement as the Engineer may direct.

Payment. The price bid per cubic yard for filter sand, includes securing, transporting and placing the sand, together with all screening, washing or other cleaning which may be necessary to make it conform to the above requirements, and the final measurement shall be made in position after settling one week with water and with the filter in operation. A. H.

**191. Specifications and Contract for Architect's Services.** The city of New York has found it advisable to prepare a form of Specifications and contract for the engagement

of the services of architects. Modern building construction has become so complicated and involves of necessity professional services of so many kinds that it requires a very clear and specific understanding between the owner and the architect as to the exact duties of the latter. This understanding is usually limited to a more or less informal agreement which is often not reduced to writing. As a result there are very frequently serious misunderstandings between the owner and the architect as to his duties and obligations, and the time has evidently arrived when a regular form of agreement should be entered into between these two parties. Evidently a similar form might be employed in the engagement of an engineer when his remuneration consists in a fixed percentage of the cost of the work. The following form of contract has been prepared under the direction of Professor Waite, who is himself a well-known authority on the law of engineering contracts. Omitting the provisional introductory forms and the final official certificates, the document is as follows:

**Words Defined.**

1. That wherever in this agreement the phrase "party of the first part" or the word "City," or the words "Commissioner(s)," "President," or "Board," or a pronoun in the place of either of them is used, the name or names shall be deemed and taken to mean and intend the party of the first part to this agreement.

2. That wherever in this agreement the word Architect(s), or a pronoun in its place, is used, the same shall be deemed and taken to mean and intend the party of the second part to this agreement.

**Preliminary Drawings to be Submitted for Approval.**

3. That the said Architect(s) will, at their own proper cost and expense, by or before the.... .... day of............, 190.., furnish to the said Commissioner(s) preliminary studies, sketches and drawings, consisting of general plans of each floor and general elevations and cross-sections, with general outlined specifications sufficient to show general character, construction and interior finish of the proposed building or structure, together with an estimate of the cost of the said building or structure, as in said drawings and specifications set forth and described, which said preliminary drawings and specifications shall be submitted to the said Commissioner(s) for his or their approval, and that if the

said preliminary drawings, specifications and estimates herein described are not satisfactory to said Commissioner and approved by him, then the said Architect(s) shall and will revise and correct said plans, elevations, sections and specifications so that they shall conform to the suggestions, criticisms and requirements of the said Commissioner(s), and so that the estimate and cost shall be well within the appropriation or funds available for the said building or structure.

**Drawings and Specifications for Bids or Estimates.**

4. That the said Architect(s) will thereafter, at their own proper cost and expense, and within ........days after the approval by the Commissioner(s) of the said preliminary drawings and specifications (or the revisions thereof), provide and furnish to the said Commissioner(s) complete plans, elevations, sections and drawings of the exterior and interior, and complete working drawings with construction details sufficiently shown, and with figured dimensions given as shall, with the specifications furnished and hereafter required, enable prospective bidders and contractors to prepare and make accurate and reliable estimates of the quantities, quality and character of the several kinds of labor and materials required to erect and complete the said building, structure, works, plan, apparatus or equipment in a first-class workmanlike manner and for the purposes and uses intended.

**Details.**

5. That thereafter and during the erection and construction of the above, entitled work the Architect(s) shall furnish all the detail and working plans, models, drawings and sketches necessary and proper to enable the builder or contractor to provide the materials and apparatus and to build, erect, construct and complete the whole structure contemplated and comprised in the above title in a good, prompt, efficient and satisfactory manner; such plans and drawings to include all the various parts and portions of the building, structure, works, plant, apparatus and equipment, and all features of decoration and ornamentation desirable and proper to make it an artistic architectural, or engineering production.

**Pipes, Conduits, etc., to be Shown.**

6. That such plans and drawings shall include complete detail and working plans, elevations and sections, which shall show not only all structural features, ornamentation and decoration, but also all air, gas, steam, hot and cold water, refrigerating,

power, heating, ventilating, sanitary and electric pipes or conduits, with all connections, valves, gates, switches, cut-outs, etc., and the location of all appliances and machines operated and supplied thereby; with arrows or indexes to show the directions of the currents therein when the plant is properly working.

Number of Sets of Drawings.

7. That six sets of blue or sun prints of such plans, elevations, sections and drawings shall be furnished to the Department or Board for its use for bidders and contractors during the period that the above-entitled work is being advertised, and until the contract(s) therefor shall have been let or awarded, and that one set shall be furnished and delivered to the said Department or Board for its uses and purposes during the erection and construction of the works, and three complete sets of such plans, elevations and drawings of the said works shall be furnished to the Contractor(s) having in charge the particular work for which they are or were designed and made; and upon the final completion of the building, structure, works and appliances, the said Architect(s) shall furnish to the said Department or Board a complete set of plans, elevations and sections revised and corrected so as to agree and conform to all material changes and alterations that shall have been made, so that such plans, elevations and sections shall show the exact dimensions, shapes and locations of the said building, structure, works, plant or apparatus as it or they shall have been actually built and completed.

Personal Services.

8. That the Architect(s) shall give their personal attention to the preparation and completion of the plans, and to the erection and completion of the said work, and that only competent and skillful architects and engineers, draughtsmen, superintendents and inspectors shall be employed upon such plans and drawings and about the said work.

Builders and Sub-Contractors not to be Employed

9. That the said Architect(s) shall not engage, employ or require the builder or contractor, or any sub-contractor to furnish any part or portion of this work, which is the subject of this employment, to prepare, provide or furnish any of the specifications, computations, plans and detail or working drawings, for or on account of the said building, structure, works or apparatus, or any portion thereof, but shall undertake, perform and furnish such services and provide such sketches, plans, details and other work-

ing drawings, as shall be required for the erection, construction, decorations and ultimate completion and operation and use of the said building, structure, works or apparatus, at his own cost and expense; but that nothing herein contained shall relieve the contractor from providing and furnishing all shop-drawings, templets, reverse templets, patterns, forms, moulds, models, tackle, etc., necessary and proper for the prompt, successful and rapid progress and early completion of the said building, structure, works, plant, apparatus and equipment.

**Complete Specifications.**

10. That the said Architect(s) shall prepare, provide and furnish *full and complete specifications* in detail for the above entitled works, which shall describe the different parts and portions of the building, structure, works, plant, apparatus or equipment proposed and all the several kinds of materials, parts and members thereof, and the manner and method to be adopted and employed for working, developing, erecting, constructing and fully completing the various parts and portions of the works, so as to carry out the intent and purpose for a complete structure for the uses and purposes for which it is intended.

**Materials, etc., to be Described**

11. That such specifications shall not describe materials and apparatus and equipment in the names of patentees, manufacturers and dealers who have a monopoly therein, but shall describe and specify materials, furnishings, equipment and process in such a manner and by such descriptions, designs, tests, requirements and specific results that they may be purchased and obtained in open, competitive market; and as shall not violate the provisions or spirit of section 1554 of The Greater New York Charter.

**Property in Drawings.**

12. That the said drawings, including the plans, elevations and sections, and the specifications prepared, provided and furnished by the said Architect(s) are instruments of service, such *original* plans and drawings and *original* specifications are to be and shall be taken to be and remain the property of the said Architect(s), who reserve and retain all rights to the incorporeal designs exhibited therein and thereon.

**Supervision, Direction and Inspection.**

13. That the said Architect(s) from the beginning of the work described shall take full charge and supervision of the building, structure, plant, works, apparatus and equipment and shall furnish necessary and proper instructions, directions and draw-

ings to the contractor, his superintendents and foremen, and shall obtain and secure a first-class, workmanlike job in every particular; that he or they will inspect, examine, test and accept or reject all materials of construction provided, furnished and delivered for and to be used in or to become a part of the said building, structure, works or apparatus, whether such materials be crude or wrought, finished or ornamented materials, and will examine, inspect and accept, approve or reject, all the workmanship, skill, artistic or otherwise, that is furnished for or wrought upon or into the said building, structure or works, and so far as they conduce to the architectural, artistic or engineering features or the stability or permanence of the works as the said materials or work may or may not conform strictly to the contract, specifications and plans and to good and workmanlike construction, that he or they shall refuse, reject and require to be removed all materials or work which do not fully comply with the specifications, contract, plans and drawings prepared therefor, and will require that they be replaced by materials and work which shall conform to and with the said contract, specifications, plans and drawings and that are proper, appropriate and necessary to a complete and first-class, workmanlike job.

14. That the said Commissioner(s) may designate or appoint a building superintendent for the general supervision and inspection of the work and such inspectors as may to him seem necessary for the proper inspection and supervision of the work to enable the Commissioner(s) to properly certify to the satisfactory progress and completion of the work and to the payments under the contract therefor, by and on behalf of the City. That the said Architect(s) will furnish to such building superintendent and inspectors all information and assistance necessary to enable them to properly inspect and report upon any work or materials furnished for and wrought into the building, structure, works, plant, apparatus or equipment. **Building Superintendent.**

15. Generally, that the said Architect(s) will furnish and perform all those services required for the erection and construction of the building or structure and plants, and the heating, lighting, power, including ventilation, sanitary and electrical arrangements and appliances, and will supervise and **General Undertaking.**

direct and promote the erection and completion for use and occupation of the said building, structure, works and plant of which this contract is the subject.

**Employment of Specialists** 16. That the said Architect(s) will at their own cost and expense secure and engage the services of such engineering or architectural specialists as they may require or as may be necessary and proper to skillfully and properly design, plan, adapt and adjust the various heating, lighting, power, ventilating, sanitary, electrical, elevator, etc., plants, apparatus and equipment for the said building, structure or works or for the ornamentation and decoration thereof, and that the said designs, plans and specifications for such heating, lighting, power, ventilating, sanitary and electric elevator plants or equipment shall, in the discretion of the Commissioner(s), be submitted to and reported upon by some independent consulting engineer of experience and reputation, to be selected and determine by the Commissioner(s), President or Board, which said consulting engineer shall be paid for his services by the said Department or Board of the City.

**Lines and Levels.** 17. That the said Architect(s) shall and will design, plan and conduct their work with reference to and in strict conformity with the lines, levels and grades given and determined by the City Surveyor, who shall be selected by the said Commissioner(s) to give and determine the same.

**Fees or Compensation.** 18. That the City hereby retains and employs the said Architect(s) to perform the aforesaid services, and for and in consideration thereof and of the observance and performance of the conditions and stipulations herein contained, it agrees to pay to the said Architect(s) in full compensation therefor the following fees or prices:

(*a*) Five per cent. (5 per cent.) upon the total cost of the building, structure, works, plant, apparatus or equipment, including all fixtures necessary to render the building, structure, works or apparatus fit for occupation or use, but not including furniture or fixtures, nor the heating, lighting, ventilating, electrical, sanitary or elevator equipment, plant or apparatus which are not or shall not be designed and supervised by the said Architect(s).

(*b*) That no special rate for monumental or decorative work or for designs for furniture, cases or apparatus in excess of the general compensation

of five per cent. (5 per cent.) upon the cost thereof shall be charged, and that no extra charge shall be made for mural or ceiling decorations, any custom of Architect(s) to the contrary notwithstanding.

(c) That the fees of consulting architects and engineers above referred to who may be retained and employed by the Commissioner(s) to examine, revise and report upon the said designs, plans, drawings and specifications of the said Architect(s), as hereinbefore provided, shall be paid by the City and not by the said Architect(s).

19. That the party of the first part shall pay to the said Architect(s) for partial service as in case of the abandonment or suspension of the work, as follows: **Fees for Partial Services.**

(*a*) For preliminary studies and sketches, consisting of drawings, such as ground plan and general elevation and perspective view of exterior, a fee of one per cent. (1 per cent.) of the proposed or estimated cost of the work upon the completion and delivery of such preliminary studies, sketches, etc., the amount so paid to be credited on the total commission of five per cent. (5 per cent.) of the actual cost, whether the estimated cost of the building prove greater or less than the actual cost. **Preliminary Studies.**

(*b*) For a full set of preliminary drawings, including such preliminary studies or sketches, etc., and such additional elevations, plans, sections, general working drawings, specifications and details as are or may be necessary to make a close estimate of the full cost as provided in sections (3) to (11) of this agreement as shall be necessary for advertising and inviting bids or estimates from contractors for the undertaking of the erection, construction and full completion thereof, a fee of two and one-half per cent. (2½ per cent.) of the price or sum at which the contract is awarded, or if the award be delayed for more than sixty days, then of the estimated cost. **Drawings, etc., for Bids**

(*c*) For all details, working-drawings and models necessary and proper for the working, finishing and decorating of all materials, stuffs, members and parts and for their incorporation and adjustment and for the skillful construction, erection and ultimate completion of the building, structure, works, plant, apparatus, and equipment, a fee of one per cent. (1 per cent.) **Details.**

Supervision and Inspection. (*d*) For all services performed in the inspection, testing, acceptance and rejection and re-acceptance of materials and work, including the general supervision and direction, and including all supervision, direction and instruction to the contractor(s) or his representatives, as may be necessary for the ultimate, final and full completion of the work, and the determination of all questions and disputes, as herein provided, the balance of one and one-half per cent. (1½ per cent.)

Basis of Charges. 20. That the said entire fee shall be paid upon the actual cost of the building, structure, works or apparatus, and that no additional charge shall be made for alterations and additions to or in the contract and plans or for any additional time or services whatever, which is required for such alterations or changes either in the specifications or plans or in the building, structure, works, plant, apparatus or equipment itself, except and only upon a written supplemental agreement by and between the parties hereto, in which the said additional compensation shall be fixed and determined. That no allowance shall be made for traveling expenses to or from the works, or in connection therewith, and that no additional or extra charges shall be made or allowed for any professional consultations or conferences, either with the said Department or Board or with any other Department of the City, for and in connection with the said work, or with the professional or consulting engineers and architects in regard thereto. The compensation herein agreed upon shall include all fixtures necessary to render the building, structure, works, plant or apparatus fit for occupation and use, but that no extra compensation shall be asked or allowed for furniture or other articles, unless they be designed by the Architect(s) and erected or placed under his inspection and direction at the express request of the said Commissioner(s) or by resolution of the said Board.

Conferences, Hearings, etc. 21. That the above fees shall cover all professional advice and services required by the said architect(s) in the design, erection, construction and completion of the said building, structure, works, plant or apparatus, and also all conferences, hearings and meetings necessary and proper to determine any questions or disputes between the contractor or subcontractors and the said party of the first part, and

which questions and disputes it may be provided shall be heard and determined by the Architect(s) in the contracts between the said party of the first part and the said contractor(s).

22. That payments to the said Architect(s) shall be made as his work progresses, and at succeeding stages of the work as follows: Upon the completion and delivery of the said plans, elevations, sections, general working drawings with constructive details sufficiently shown, and the dimensions figured to enable bidders or contractors to prepare accurate and reliable estimate of the cost thereof, and the completion and delivery of full and complete specifications for all branches and classes of work necessary to the full and ultimate completion, use and occupation of the said building and structure, as provided in Clause 19 (*b*), two and one-half per cent. (2½ per cent.); upon the completion of all details, working drawings, plans, sections and models, as provided in Clause 19 (c), one per cent. (1 per cent.), and upon the completion of said building, structure, works, plant, apparatus and equipment and their final acceptance by the City, one and one-half per cent.), or the balance that may be due and owing of the full fee or percentage of the actual cost. **Time and Manner of Payment.**

23. That if, at any time, the said Architect(s) shall abandon or unreasonably delay the preparation and completion of the plans, elevations, sections, details and working drawings, and the complete specifications, within the time herein specified, or as may be required by the said Commissioner(s) and as may be necessary or proper to enable the contractor(s) to prosecute the said building, structure, works, plant, apparatus or equipment with dispatch and reasonable safety so as to insure its completion within the time designated in the contract therefor, the said Commissioner(s), President or Board shall have the power to notify the said Architect(s) to discontinue all services and work provided for under this contract, by written notice to be served upon the said Architect(s) either personally or by leaving the same at their residence, and thereupon the said Architect(s) shall discontinue the said services or such part thereof as the said Commissioner(s) may designate, and the said Commissioner(s) shall have the power to employ other architects, by contract or otherwise, as he may deem advisable to perform and **Abandonment or Delay.** **Power to Employ Others.**

complete the said services and work herein described, or such part thereof as he may deem necessary, and the remuneration, pay or fees of the said Architect(s) shall be determined by the scale of prices or fees herein given, it being expressly agreed and understood that the said Architect(s) shall be paid only such fees as they shall have fully earned, and as shall be due and owing under the express terms of this agreement. That whenever the City or its appropriate officer(s) shall act under this clause, or in the event of the death of the Architect(s), all drawings, plans, elevations, sketches, sections and models and all specifications, estimates, measurements and data pertaining to the building, structure, works, plant, etc., or prepared for them under the terms of or in fulfillment of this contract, shall be delivered within twenty days to the said Commissioner(s), President or Board, or to his or its authorized agent, and if the said Architect(s) shall fail or refuse, upon demand being made, to so deliver said instruments, estimates and data, then the said Architect(s) shall forfeit all rights to any further compensation under this contract for or on account of any services rendered or to be rendered.

**Delivery of Plans, etc., in Case of Abandonment, Delay or Death**

**Suspension.**

24. That if, for any reason, it becomes necessary to postpone, suspend, delay or abandon the building, structure, works or apparatus for which these services are engaged and employed, then the said Architect(s) shall be paid only such fees as they shall have fully earned, and as shall be due and owing by the express terms of this agreement, and such postponement, suspension, delay or abandonment shall not give any cause of action for damages or for extra remuneration to the said Architect(s).

**Officers of City Not Bound Personally.**

25. That the payments herein provided for are to be made out of the moneys provided by the party of the first part, for the construction, erection and completion of the above entitled building, structure, work, plant or apparatus, and that these presents do not bind the said Commissioner(s) individually to make any payment or payments hereunder or on account hereof. That his or their action in the premises is binding upon the said City and its successors, and the fund hereby created for such purpose, in conformity with the statutes and The Greater New York Charter, and the acts in addition and supplemental thereto, or any amendments thereof, and un-

der which said Commissioner(s) was or were appointed, and under and by virtue of which he or they acted in these premises

26. That the Architect(s) will be responsible for all claims made against the said City for any infringements of copyright or patent-right for or on account of the adoption and use of any designs, plans, drawings or models furnished by the said Architect(s) and used in the construction or decoration of the said building, structure or works, plant or apparatus. **Copyright.**

27. That this contract shall not be binding or of any force unless the Comptroller of The City of New York shall indorse hereon his certificate that there remains unexpended and unapplied, as provided in The Greater New York Charter, a balance of the appropriation or fund applicable thereto sufficient to pay the estimated expense of executing this contract, as certified by the officers making the same. **Charter, Section 149.**

28. That the cost of the said building, works and apparatus designed, planned and illustrated, including the Architect's fees and the cost of necessary surveys and inspection, shall be kept well within the sum of ........................ ($........). **Cost to be Limited.**

29. That it is understood and intended by the parties hereto, that the party of the second part shall provide and furnish the personal services of .......
.......... .......... ........................
and that this contract may not be assigned, sublet or transferred, without the express consent in writing of the said Commissioner(s), President or Board. **Personal Services.**

In witness whereof, the said The City of New York has, by the said Commissioner(s), executed this contract on behalf of the said party of the first part and the said party of the second part has executed this contract the day and year first above written, and the said parties hereto have executed this agreement in triplicate, one part of which is to remain with the said Commissioner(s), one other is to be filed with the Comptroller of The City of New **Execution.**

York, and the third is to be delivered to the said party hereto of the second part the day and date herein first written above

Signatures.

........................[L. S.]
*Commissioner(s).*
........................[L. S.]
*President.*
........................[L. S.]
*Secretary.*
........................[L. S.]
*Architect(s).*

(Seal.)

J. C. W.

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## CONTRACTOR'S BONDS.

192. **Contract Bond or Surety.** It is a very general custom in all important work to require the contractor to furnish a bond for the faithful and complete performance of his contract. Sometimes these bondsmen or sureties sign with the contractor, as in the case of the St. Louis contracts, exemplified in article 170. It is more usual, however, to make this bond a separate document, following immediately the signatures of the contract itself.

Bonds are always executed under seal, and are therefore special contracts, since the bondsmen are not usually paid a consideration for the service rendered, and a sealed contract does not require a consideration to enforce it.

In case the original contract and specifications are deviated from in the execution of the work to any material extent, without the consent of the bondsmen, these latter are thereby released from their bond. Since such changes are nearly always made in the execution of engineering work after the contracts are signed, and since these are usually made without consulting the bondsmen, these latter are as a rule thereby released from all obligations, and the bond becomes of no effect. Even though the bondsmen be consulted in the matter of changes, they are not obliged to give their consent, and usually perhaps

would not, in which case material changes could be made only by releasing the bondsmen.

To provide for such changes, without releasing the bondsman, the following clause may be added:

*And the said suret . . . hereby stipulate . . . and agree . . . that no change, extension, alteration or addition to the terms of the contract or specifications shall in any wise affect . . . obligation on this bond.*

The form of bond given below is that used by the city of Boston, and may be taken as a general type of such a document.

## CONTRACT BOND OR SURETY.

*Know all Men by these Presents,*
That we —— —— —— —— are held and firmly bound unto the city of Boston, in the sum of —— dollars to be paid to the city of Boston, or its certain attorney, its successors and assigns, for which payment, well and truly to be made, we bind ourselves, our heirs, executors and administrators, jointly and severally, firmly by these presents.

*The Condition of this obligation is such that* if the above-bounden —— —— shall well and truly keep and perform all the terms and conditions of the foregoing contract for excavation for stripping and shallow flowage and for building two roads, at Basin No. 5, in Southborough, on —— part to be kept and performed, and shall indemnify and save harmless the said city of Boston, as therein stipulated, then this obligation shall be of no effect; otherwise it shall remain in full force and virtue.

*In witness whereof* we hereto set our hands and seals on this —— day of ——, in the year eighteen hundred and ninety-four.

—— —— [SEAL.]
—— —— [SEAL.]
—— —— [SEAL.]
—— —— [SEAL.]
—— —— [SEAL.]

Signed and sealed in presence of

—— ——.
—— ——.
—— ——.
—— ——.

193. **Indemnity Bond.** The following is a common form of bond to cover all liens which may arise from a failure of the contractor to pay for his labor and materials:

*Know all Men by these Presents:* That —— —— of —— as principal, and —— —— of —— as surety, are held and firmly bound unto the —— —— in the penal sum of —— dollars, to the payment of which well and truly to be made we bind ourselves, our heirs, executors, administrators and assigns firmly by these presents.

Signed this —— day of ——, 189–.

*The Condition of the above Obligation is such that:*

WHEREAS, the said —— —— has this day entered into a contract in writing with the said —— —— for the grading and construction of a certain —— with ditches, roadways and other works connected therewith, as more specifically set forth in said contract:

NOW, THEREFORE: If the said —— —— shall well and truly perform his part of said contract, and each and every covenant and agreement therein contained, and shall indemnify and save harmless the said —— —— from and against all damages which it may sustain by reason of liens for labor and materials furnished for said work, or by reason of the failure of said —— —— to pay the wages and earnings of any of the —— laborers or mechanics employed by him as such contractor, in and about said work; or by reason of his failure to pay for any materials, provisions or goods of any kind furnished, or by reason of any just debt incurred in carrying on said work; and if the said —— —— shall pay to the said —— —— all sums of money, damages or costs and expenses which it may be compelled to pay, or which it may sustain by reason of his failure as aforesaid, and if the said —— —— shall pay all laborers, mechanics and material men, and persons who may have supplied provisions or goods of any kind, all just debts due to such persons, or to any person to whom any part of such work was given, then this obligation shall be void, otherwise of full force and effect.

—— —— [SEAL.]
—— —— [SEAL.]

# APPENDICES.

## APPENDIX A.

### PRELIMINARY SURVEYS AND EXAMINATIONS FOR BRIDGE RENEWALS.

The following instructions to assistant engineers are used by the engineer of bridges and buildings on the C., M. & St. P. R'y, and are inserted here as an illustration of the scope and character of the inquiries and investigations necessary for an intelligent solution of the problem in hand. It is only by means of such complete and detailed information that all future contingencies can be forseen and provided for, so that there shall be no "unexpected" to happen. It is a common saying that "the unexpected always happens." In good engineering, "it is only the unexpected which can happen," since what was anticipated has been fully provided against. In the *best* engineering designs, however, every possible contingency has been foreseen and provided for, so there is no unexpected left which can happen, and hence security and permanence are assured in advance. The following instructions are a good illustration of this kind of preliminary survey of the problem which puts the engineer in a position to perfectly fit the design to all the conditions of the problem:

*Instructions to Assistant Engineers in Regard to Surveys for the Renewal of Wooden Bridges with Permanent Structures.*

(1) Gather information from the chief engineer's office and from the office of the engineer and superintendent of bridges and buildings relative to the grade, alignment, right-of-way for embankment and borrow pits, second track construction, contracts relating to crossings or cattle passes, recommenda-

tions already made by others as to style of reconstruction and any other matters that are liable to have a bearing on work in question

(2) Determine the elevation of base of rail above an assumed datum across the bridge and for a distance of 1,000 feet on each side of it, at intervals of 100 feet, or less when the irregularities of the track make it necessary.

(3) Consider the question of changing grade and note the kind, condition and depth of ballast as well as other points that will assist in determining the expense and practicability of making a change.

(4) Obtain particularly notes of the ground surface that will be covered by the proposed structure or embankment, by determining its elevation on the center line of bridge and when necessary on each side of same. These heights may be measured from the base of rail at each bent or panel point but should refer to the datum used in the survey, and additional notes should be made of intermediate irregularities that would concern the height of pedestals located between bents.

(5) Establish and note two bench marks on solid objects, conveniently located, one each way from the bridge, and which are unlikely to be disturbed during the construction of the permanent structure. For ordinary cases a track spike driven in a telegraph pole will be suitable.

(6) Note the alignment of the track at the structure and consider whether there is any evident reason for changing same.

(7) Consider the question of second track construction as concerning any change in alignment or in location of bridge. Conclude on which side of the present track the second track should be constructed and make note of the grounds for your conclusion.

(8) When track across the bridge or near the bridge is curved make full notes of elevation of outer rail. If the point of curve is so located that the elevation of outer rail on bridge is varying, determine by eye the location of point of curve and of the point where the elevation is commenced. On iron bridges the elevation should be constant when practicable.

(9) Take notes for a sketch of the water course for a sufficient distance on each side of the bridge, to determine whether a change in location of channel or an improvement in the channel is advisable, and indicate your recommendations in this regard, remembering that the most favorable condition for a bridge is usually a deep channel at right angles to the railway for some distance above and below the bridge. Contours in the immediate vicinity of the bridge should be sketched in.

Ordinarily this can be done with sufficient accuracy by the eye, or by taking a few offsets.

(10) Ascertain the nature of foundations, whether soft, requiring pile foundations, or of sand, or of hard clay, or of rock. Reports should state the character, depth and dip of the strata.

(11) Ascertain present, ordinary and extreme high water marks. Inquire into cause of high water; whether by ordinary heavy rains, by water-spout, by damming from accumulations of drift or ice, or by overflow from other water courses, or from other causes which may be apparent.

(12) Note the probability of ice, drift-wood, hay, cornstalks, fencing, etc., lodging against the proposed iron bridge.

(13) Take notes of the size of channel, area of waterway required, direction of current, etc.

(14) Ascertain if there is to be provided under the bridge a public or private roadway, wagon-pass or cattle-pass, with dimensions and conditions controlling the same.

(15) If any portion of the bridge is to be filled, make an examination of the ground and state where the material can be obtained, and whether inside of the boundaries of the right-of-way, or on land which will have to be purchased.

(16) Ascertain whether any additional right-of-way is required for any purpose connected with the work, and if so note location and amount.

(17) Examine as to a suitable location for a stone yard, and for the storing of piles, timber and iron-work; also as to convenient locations for derricks and what provision will be required for suitable anchorage for derrick guys.

(18) If the proposed reconstruction involves any question of purchasing land or privileges, report the situation with advice, but avoid conversation with property owners which would in any way interfere with relations that may be established later between them and an agent authorized to make purchases or settle claims.

(19) Inquire as to the accommodations for boarding and lodging for workmen and how they can get to and from their work.

(20) Inquire into the condition of train service at the location with regard to the frequency of trains and the speed at which they ordinarily run over the bridge.

(21) If piles are to be driven, make your recommendation as to whether they should be driven with a land or track driver, and if with a track driver, state the nearest side-track to which it must retreat for passage of trains.

(22) Make preliminary estimates of the cost of the permanent structure, taking your prices from the tables of cost of

iron bridges and abutments which are furnished you and from them make your recommendation for the permanent bridge.

(23) Make your recommendations as to the angles of piers and abutments, remembering that a square span is one in which its ends are at right angles to its longitudinal axis, and in a skew span the angle of skew is the enclosed angle between the end of the span and a line at right angles to its longitudinal axis.

(24) Make your recommendations as to what riprapping is required, with the amount and method of using it.

(25) Advise what is the best season of the year in which to do the work with reference to high water, ice, cold weather, interruption of traffic, facility for obtaining labor and material, etc.

(26) Report any information you can obtain with reference to using local material in the work, such as piles, timber, lumber, stone, sand, brick, etc.

(27) Avoid confusing terms in your notes. For instance the term "base of rail" is preferable to "grade." See B. & B., Rule 7 g.

FINALLY. After obtaining information on the points hereinbefore mentioned and all other data which you can find within your reach, consider the question of renewal just as if you had to make the full decision and were responsible for building the best bridge with the greatest economy and least risk; and make your report in such shape that the draughting office will have all the instruction which it requires for making the plans. This information may be furnished in writing and on a profile and map, and you are cautioned that your work will be judged by your giving the fullest accurate information with the fewest notes and the least amount of drawing.

O. B.

# APPENDIX B.

## General Specifications for the Testing of Hydraulic Cements, adopted by a Board of U. S. Engineer Officers in 1901, and used by the Engineer Department of the U. S. Army.[1]

### TESTS TO BE MADE.

For selecting Portland and Puzzolan cement from among the brands offered, the Board recommends that the following tests be made:

1. For fineness of grinding.
2. For specific gravity.
3. For soundness, or constancy of volume in setting.
4. For time of setting.
5. For tensile strength.

For Natural cement we recommend the omission of the specific gravity and soundness tests.

On the works the Board recommends simple tests when the more elaborate tests can not well be made.

In determining the minimum requirements for cements given in the subjoined specifications we recognize that many cements that attain only fair strength neat and with sand in a short time and show marked gains of strength on further time will fulfill the requirements of the service, and that unusually high tensile strength attained in a few days after gauging is often coupled with a small or negative increase in strength in further short intervals. Unusually high tests in a short time after gauging should be regarded with suspicion, although some well-known brands of American cements show great strength in short-time tests and, so far as observed, are reliable in air and fresh water. Cement offered under such known brands should show their characteristic strength and other qualities or be suspected as spurious or adulterated, if not rejected, even though the minimum requirements of the specifications are met. The practice of offering a bonus or free gift of money in addition to the contract price for cement testing above a fixed high point should be prohibited as unnecessary, for cements so obtained are likely to be unsound in a manner not easily detected in the time usually available in testing.

It is believed that most of the very high testing Portland cements have lime in excess, the effect of which is temporarily

[1] The members of this Board were Major Wm. L. Marshall, Major Smith S. Leach, and Captain Spencer Crosby

masked by the use of sulphate of lime. Overlimed cements so treated are unfit for use in sea water. For such uses a chemical analysis should be required, and the quantity of sulphuric acid, as well as magnesia, be limited to a low percentage. It is not yet known that sulphate of lime in quantity less than 2 per cent is injurious to cements to be used in fresh water or in air. It masks expansives that might ultimately cause the destruction of the work, but it is not known whether this effect is permanent. Its addition is now deemed necessary to control time of setting. It makes a quick-setting cement slow setting, at the same time increasing tensile strength acquired in short time.

## MANIPULATION OF CEMENTS FOR TESTS.

### *I. Fineness.*

Place 100 parts (denominations determined by subdivisions of the weighing machine used) by weight on a sieve with 100 holes to the linear inch, woven from brass wire No. 40, Stubb's wire gauge; sift by hand or mechanical shaker until cement ceases to pass through.

The weight of the material passing the sieve plus the weight of the dust lost in air, expressed in hundredths of the original weight, will express the percentage of fineness. In order to determine this percentage the residue on the sieve should be weighed.

It is only the impalpable dust that possesses cementitious value. Fineness of grinding is therefore an essential quality in cements to be mixed with sand. The residue on a sieve of 100 meshes to the inch is of no cementitious value, and even the grit retained on a sieve of 40,000 openings to the square inch is of small value. The degree of fineness prescribed in these specifications (92 per cent) for Portland through a sieve of 10,000 meshes to the square inch is quite commonly attained in high-grade American cements, but rarely in imported brands. On the Pacific coast, where foreign cements only are in the market, this requirement may be lowered for the present to 87 per cent on No. 100 sieve.

### *II. Specific Gravity.*

The standard temperature for specific gravity determinations is 62 degrees F., but for cement testing temperatures may vary between 60 and 80 degrees F. without affecting results more than the probable error in the observation.

Use any approved form of volumenometer or specific gravity bottle, graduated to cubic centimeters with decimal sub-

divisions. Fill instrument to zero of the scale with benzine, turpentine, or some other liquid having no action upon cements.

Take 100 grams of sifted cement that has been previously dried by exposure on a metal plate for twenty minutes to a dry heat of 212 degrees F., and allow it to pass slowly into the fluid of the volumenometer, taking care that the powder does not stick to the sides of the graduated tube above the fluid and that the funnel through which it is introduced does not touch the fluid.

Read carefully the volume of the displaced fluid to the nearest fraction of a cubic centimeter. Then the approximate specific gravity will be represented by 100 divided by the displacement in cubic centimeters.

The operation requires care.

### *III. Setting Qualities and Soundness.*

The quantity of water and the temperature of water and air affect the time of setting. The specifications contemplate a temperature varying not more than 10 degrees from 62 degrees F., and quantities of water given herein:

For Portland cements use 20 per cent of water.

For Puzzolan cements use 18 per cent of water.

For Natural cements use 30 per cent of water.

Mix thoroughly for five minutes, vigorously rubbing the mixture under pressure; time to be estimated from moment of adding water and to be considered of importance.

Make on glass plates two cakes from the mixture about three inches in diameter, half an inch thick at middle, and drawn to thin edges, and cover them with a damp cloth or place them in a tight box not exposed to currents of dry air. At the end of the time specified for initial set apply the needle one-twelfth of an inch diameter weighted to one-fourth of a pound to one of the cakes. If an indentation is made the cement passes the requirement for initial setting, if no indentation is made by the needle it is too quick setting. At the end of the time specified for "final set" apply the needle one twenty-fourth of an inch diameter loaded to one pound. The cement cake should not be indented.

Expose the two cakes to air under damp cloth for twenty-four hours. Place one of the cakes, still attached to its plate, in water for twenty-eight days, the other cake immerse in water at about 70 degrees temperature supported in a rack above the bottom of the receptacle; raise the water gradually to the boiling point and maintain this temperature for six hours and then let the water with cake immersed cool. Examine the cakes at the proper time for evidences of expansion and distor-

tion. Should the boiled cake become detached from the plate by twisting and warping or show expansion cracks the cement may be rejected, or it may await the result of twenty-eight days in water. If the fresh-water cake shows no evidences of swelling, the cement may be used in ordinary work in air or fresh water for lean mixtures. If distortion or expansion cracks are shown on the fresh-water cake, the cement should be rejected.

Of two or more cements offered, all of which will stand the fresh-water cake test for soundness, the cements that will stand the boiling tests also are to be preferred.

### *IV. Tensile Strength.*

*Neat Tests.*—Use unsifted cements. Place the amount to be mixed on a smooth, nonabsorbent slab; make a crater in the middle sufficient to hold the water; add nearly all the water at once, the remainder as needed; mix thoroughly by turning with the trowel, and vigorously rub or work the cement for five minutes.

Place the mold on a glass or slate slab. Fill the mold with consecutive layers of cement, each when rammed to be one-fourth of an inch thick. Tap each layer 30 taps with a soft brass or copper rammer weighing 1 pound and having a face three-fourths of an inch diameter or seven-tenths of an inch square with rounded corners. The tapping or ramming is to be done as follows: while holding the forearm and wrist at a constant level, raise the rammer with the thumb and forefinger about half an inch and then let it fall freely, repeating the operation until the layer is uniformly compacted by thirty taps.

This method is intended to compact the material in a manner similar to actual practice in construction, when a metal rammer is used weighing 30 pounds, with a circular head 5 inches in diameter falling about 8 inches upon layers of mortar or concrete 3 inches thick. The method permits comparable results to be obtained by different observers.

After filling the mold and ramming the last layer, strike smooth with the trowel, tap the mold lightly in a direction parallel to the base plate to prevent adhesion to the plate, and cover for twenty-four hours with a damp cloth. Then remove the briquette from the mold and immerse it in fresh water, which should be renewed twice a week for the specified time if running water is not available for a slow current. If molds are not available for twenty-four hours, remove from the molds after final set, replacing the damp cloth over the briquettes. In removing briquettes before hard-set great care should be exercised. Hold the mold in the left hand, and, after loosening the latch, tap gently the sides of the mold until they fall apart. Place the briquettes face down in the water trough.

For neat tests of Portland cement use 20 per cent of water by weight.

For neat tests of Puzzolan cement use 18 per cent of water by weight.

For neat tests of Natural cement use 30 per cent of water by weight.

Nearly all this water is retained by Portland cement, whereas only about one-third of the gauging water is retained by Puzzolan or Natural cements; from this it follows that an apparent condition of plasticity or fluidity that ultimately little injures Portland paste, very seriously injures Puzzolan or Natural mortars and concretes by leaving a porous texture on the evaporation of the surplus water.

*Sand Tests.*—The proportions 1 cement to 3 sand are to be used in tests of Puzzolan and Portland, and 1 cement to 1 sand in tests of Natural or Rosendale cements. Crushed quartz sand, sifted to pass a standard sieve with 20 meshes per linear inch and to be retained on a standard sieve with 30 meshes to the inch, is to be used.

After weighing carefully, mix dry the cement and sand until the mixture is uniform, add the water as in neat mixtures, and mix for five minutes by triturating or rubbing together the constituents of the mortar. This may be done under pressure with a trowel or by rubbing between the fingers, using rubber gloves. The rubbing together seems necessary to coat thoroughly the facets of the sand with the cement paste.

It is found that prolonged rubbing, when not carried beyond the time of initial set, results in higher tests. Five minutes is the time of mixing quite generally adopted in European specifications. The briquettes are to be made as prescribed for neat mixtures.

Portland cements require water from 11 to 12½ per cent by weight of constituent sand and cement for maximum strength in tested briquettes.

Puzzolan, about 9 to 10 per cent.

Natural, about 15 to 17 per cent.

Mixtures that a first appear too dry for testing purposes often become more plastic under the prolonged working required herein.

In general, about four briquettes constitute the maximum number that may be made well within the time required for initial setting of moderately slow setting cements.

Three such batches of sand mixtures should be made, and one briquette of each batch may be broken at seven and twenty-eight days, giving three tests at each period. At least one batch of neat cement briquettes should be made.

If the first briquette broken at each date fulfills the mini-

mum requirement of these specifications it is not necessary to break others which may be reserved for long-time tests.

If the first briquette does not pass the test for tensile strength, then briquettes may be broken until six briquettes, two from each batch, have been broken at seven days, and the remaining six reserved for twenty-eight-day tests. The highest result from any sample is to be taken as the strength of the sample when the break is at the least section of briquette.

If, on the twenty-eight-day tests, the cement not only more than fulfills the minimum requirements of these specifications, but also shows unusual gain in strength, it may still be accepted if the other tests are satisfactory, notwithstanding a low seven-day, test, if early strength is not a matter of importance. Such cements are likely to be permanent.

For a batch of four briquettes, the following quantities are suggested as in accord with these specifications. Water is measured by fluid-ounce volumes, not by weight, temperature varying not more than 10 degrees from 62 degrees F.

*Portland Cement.*

*Neat.*—20 ounces of cement, 4 ounces of water. Mix wet five minutes.

*Sand.*—15 ounces sand, 5 ounces cement, 2½ ounces water. Mix thoroughly dry; then mix wet five minutes.

*Puzzolan Cement.*

*Neat.*—20 ounces cement, 3¾ ounces water. Mix wet five minutes.

*Sand.*—15 ounces sand, 5 ounces cement, 2 ounces water. Mix thoroughly dry; then mix wet five minutes.

*Natural Cement.*

*Neat.*—20 ounces cement, 6 ounces water. Mix wet five minutes.

*Sand.*—10 ounces cement, 10 ounces sand, 3½ ounces water. Mix dry; then wet for five minutes.

For measuring tensile strength, a machine that applies the stress automatically at a uniform rate is preferable to one controlled entirely by hand.

These specifications for tensile strength contemplate the applications of stress at the rate of 400 pounds per minute to briquettes made as prescribed herein. A rate so rapid as to approximate a blow or so slow as to approximate a continued stress will give very different results.

The tests for tensile strength are to be made immediately after taking from the water or while the briquettes are still

wet. The temperature of the water during immersion should be maintained as nearly constant as practicable; not less than 50 degrees nor more than 70 degrees F.

The tests are to be made upon briquettes 1 inch square at place of rupture. The specifications contemplate the use of the form of briquette recommended by the committee of the American Society of Civil Engineers, held when tested by close-fitting metal clips, without rubber or other yielding contacts. The breaks considered in the tests are to be those occurring at the smallest section, 1 inch square.

### SIMPLE TESTS.

Tests of cement received upon a work in progress must often be of much simpler character than prescribed herein.

Tests on the work are mainly to ascertain whether the article supplied is genuine cement, of a brand previously tested and accepted, and whether it is a reasonably sound and active cement that will set hard in the desired time, and give a good, hard mortar. Simple tests may give this information, and such should be multiplied whether or not more elaborate tests be made. Pats and balls of cement and mortar from the storehouse and mixing platform or machine should be frequently made. The setting or hardening qualities, as determined roughly by estimating time and by pressure of the thumbnail, should be observed; the hardness of the set and strength, by cracking the hardened pats or cakes between the fingers, and by dropping the balls from the height of the arm upon a pavement or stone and observing the result of the impact.

By placing the pats in water as soon as hardened sufficiently and raising the temperature to the boiling point for a few hours and observing the character and color of the fracture after sufficient immersion, information as to the character of the material, whether hydraulic, a Portland or Puzzolan, whether too fresh or possibly "blowy," may be speedily and quite well ascertained without measuring instruments.

Many engineers and users of cement regard such simple tests, taken in connection with the weight and fineness of the cement and the apparent texture and hardness of the mortars and concretes in the work, sufficient field tests of a material of known repute. The more elaborate tests, described above, should be made in well-equipped laboratories by skilled cement testers.

### CLASSIFICATION OF TESTS.

The tests to be made are two classes:

(1) Purchase tests on samples furnished by bidders to ascertain whether the bidder may be held on the sample to the

delivery of suitable material, should his offer be accepted.

(2) Acceptance tests on samples taken at random from deliveries, to ascertain whether the material supplied accords with the purchase sample, or is suitable for the purpose of the work, as stated in the specifications for cement supplies.

(1) *Purchase Tests.*—Under these specifications bids for Portland cements will be restricted to brands that have been approved after at least three years' exposure in successful use under similar conditions to those of the proposed work. This specification limits proposals to manufacturers of cements of established repute, and in so far lessens the dependence to be placed upon tests of single samples of cement in determining the probable quality of the cements offered, that sample packages may not be required with the proposals when the brand is known to the purchaser. When the cement is not known to the purchasing officer by previous use, a barrel of it should be required as representing the quality of cement to be supplied. A full set of tests should be made from this sample, and subsequent deliveries be required to show quality at least equal to the sample.

In this connection it is advisable in districts where well-equipped laboratories have been established, that sample packages of the cements in use in that territory, as sold in the open market, be obtained and tested as occasion offers to ascertain the characteristic qualities of the brands as commercial articles, the information to be used in subsequent purchases of cements.

When purchase samples are waived, acceptance tests should be based upon the known qualities of the brand, as shown by previous tests.

The sample barrel should not be broken further than to take therefrom the necessary samples for testing. Afterwards it should be put away in a dry place and kept for further testing, should the results obtained be disputed.

(2) *Acceptance Tests.*—The tests to be made on cements delivered under contract depend not only on the extent, character, and importance of the work itself, but also on the time available between the delivery and the actual use of the material.

(*a*) On very important and extensive works, equipped with a testing laboratory and adequate storehouses, where cement may be kept at least thirty days before being required for use, full and elaborate tests should be made, keeping in view the fact that careful tests of few samples are more valuable than hurried tests of many samples.

(*b*) On active works of ordinary character, when time will not permit full tests, and on small works where the expenses of a laboratory are not justified, the tests must neces-

sarily be limited to such reasonable precautions against the acceptance and use of unfit material as may be taken in the usually short interval between the receipt and use of the material.

Such conditions were in view in formulating the specification that proposals will be received from manufacturers of such cements only as have been proved by at least three years' use under similar conditions of exposure. Of the tests named in the specifications those for fineness, activity or hydraulicity, specific gravity, weight of packages, and accelerated tests for indications as to soundness, may be made within two days after the receipt of the material and with a very small outlay for instruments.

Cement of established repute, shown by specific gravity and fineness to be properly burnt and ground, or normal for the brand, that will set hard in reasonable time, the cakes, snapping with a clean fracture when broken between the fingers, and standing the tests above named, may be accepted and used with reasonable certainty of success. Nevertheless, packages taken at random from the deliveries should occasionally be set aside and samples taken therefrom sent to a testing laboratory for the more elaborate tests for tensile strength (and for soundness should the boiling tests not be conclusive). The final acceptance and payment for such cement as may not have been actually placed in the work should, by agreement, be made to depend upon such tests.

In all cases where cement has been long stored it should be carefully tested before use to ascertain whether it has deteriorated in strength.

Should the simple tests give unsatisfactory or suspicious results, then a full series of tests should be carefully made.

When Portland cement is in question the specific gravity and fineness tests should be made to guard against adulteration, and in all cases test weighings should be made to guard against short weights.

In cases where the amount of cement or the importance of the work will not justify the purchase of the simple apparatus required for the specific gravity, fineness, and boiling tests, the cement can be accepted on the informal tests mentioned herein, which require no apparatus whatever, but in such cases cements well known to the purchaser by previous use should be selected, and purchased directly from the manufacturer or his selling agent in order that responsibility for the cement may be fixed.

Certified tests by professional inspectors made as prescribed herein on samples taken from the cement to be shipped to the work, in a manner analogous to that customary among

engineers in the purchase of structural steel and iron, may be required in such cases.

### SAMPLING.

The entire package from parts of which tests are to be made is to be regarded as the sample tested. It should be marked with a distinctive mark that must also be applied to any part tested. The package should be set aside and protected against deterioration until all results from tests made from it are reached and accepted by both parties to the contract for supplies.

Cement drawn from several sample packages should not be mixed or mingled, but the individuality of each sample package should be preserved.

In testing it should be borne in mind that a few tests from any sample, carefully made, are more valuable than many made with less care.

The amount of material to be taken for formal tests is indicated herein where weights of the constituents of four briquettes are given, to which should be added the amount necessary for the tests for specific gravity, activity, and soundness.

In extended tests the material should be taken from the sample package from the heads and center of barrel, and from the ends and center of bag, by such an instrument as is used by inspectors of flour. All materials taken from the same sample package may be thoroughly mixed or mingled and the tests be made therefrom as showing the true character of the contents of the sample package.

In making formal tests at the work for acceptance of cement sample packages should be taken at random from among sound packages. The number taken must depend upon the importance and character of the work, the available time, and the capacity of the permanent laboratory force. For tensile strength the tests with sand are considered the more important and should always be made. Tests neat should be made if time permits.

It is not necessary in any case on a large work to test more than 10 per cent of the deliveries, even of doubtful cement, and a much less number of samples may be taken should no cause for distrust be revealed by the tests made. In very important work of small extent each package may be tested. A cement should be rejected if the samples show dangerous variation in quality or lack of care in manufacture and resulting lack of uniformity in the product without regard to the proportion of failures among samples tested.

In all cases in the use of cements the informal or simple tests of the character named herein should be constantly carried

on. These constitute most valuable tests. Whenever any faulty material is indicated by such tests, elaborate tests should be at once instituted and should the fault be confirmed, the cement delivered and not used should be rejected and the use of the brand be discontinued.

### TESTS FOR WEIGHT.

From time to time packages should be weighed in gross and afterwards the weight of neat cement and tare of the packages determined. If short weight of neat cement is indicated, a sufficient number of packages should be weighed and the average net weight per package ascertained with sufficient certainty to afford a satisfactory basis of settlement.

### RECORDS.

For tests at professional laboratories no general requirements as to records seem to be necessary. Each laboratory has its own blanks with certificate, and if a copy of the specifications be sent with the samples, the record returned should be sufficient. For records of formal tests on the work, or in a district laboratory, blank forms should be used. It is desirable to have the specification requirements stated on the form. Notations should be adopted to show for each test that the cement passed or failed or that the test was not made. No inference should be drawn from the lack of any entry other than that the recorder has neglected his duty.

### SILICA CEMENT OR SAND CEMENT.

This is a patented article manufactured by grinding together silica or clean sand with Portland cement, by which process the original cementing material is made extremely fine and its capacity to cover surfaces of concrete aggregates is much increased. The sand is an adulteration, but on account of the extreme fineness of the product it serves to make mortar or concrete containing a given proportion of pure cement much more dense, the fine material being increased in volume.

The increase in cementing capacity due to the fine grinding of the cement constituent offsets, in great degree, the effects of the sand adulteration, so that sand cement made from equal weights of cement and sand approximates in tensile strength to the neat cement and the material is sold as cement.

The extreme fine grinding also improves cement that contains expansives, but nevertheless sand cement should not be purchased in the market, but should be made on the work from approved materials, if used for other purposes than for grouting, for which it is peculiarly adapted.

Whether this material should be used in important works for mortar and concrete, the Board considers a question of cost and expediency.

Over against the saving in cement may be placed the royalty on a patented article, the cost of the plant and of manufacture, the inconvenience of attaching a manufacturing establishment to a work under construction, and other elements bearing not only on first cost of cementing material but also involving the element of time. When cement is high priced, means of transportation limited, labor, sand, and concrete materials cheap and abundant, the conditions may justify the use of sand cement on economic grounds. In any case, the cement from which the product is made should be tested precisely as other cements.

### SLAG CEMENT.

This term is applied to cement made by intimately mixing by grinding together granulated blast-furnace slag of a certain quality and slaked lime, without calcination subsequent to the mixing. This is the only cement of the Puzzolan class to be found in our markets (often branded as Portland), and as true Portland cement is now made having slag for its hydraulic base, the term "slag cement" should be dropped and the generic term *Puzzolan* be used in advertisements and specifications for such cements.

Puzzolan cement made from slag is characterized physically by its light lilac color; the absence of grit attending fine grinding and the extreme subdivision of its slaked lime element; its low specific gravity (2.6 to 2.8) compared with Portland (3 to 3.5); and by the intense bluish green color in the fresh fracture after long submersion in water, due to the presence of sulphides, which color fades after exposure to dry air.

The oxidation of sulphides in dry air is destructive of Puzzolan cement mortars and concretes so exposed. Puzzolan is usually very finely ground, and when not treated with soda sets more slowly than Portland. It stands storage well, but cements treated with soda to quicken setting become again very slow setting from the carbonization of the soda (as well as the lime) element after long storage.

Puzzolan cement properly made contains no free or anhydrous lime, does not warp or swell, but is liable to fail from cracking and shrinking (at the surface only) in dry air.

Mortars and concretes made from Puzzolan approximate in tensile strength similar mixtures of Portland cement, but their resistance to crushing is less, the ratio of crushing to tensile strength being about 6 or 7 to 1 for Puzzolan and 9 to 11

to 1 for Portland. On account of its extreme fine grinding Puzzolan often gives nearly as great tensile strength in 3 to 1 mixtures as neat.

Puzzolan permanently assimilates but little water compared with Portland, its lime being already hydrated. It should be used in comparatively dry mixtures well rammed, but while requiring little water for chemical reactions, it requires for permanency in the air constant or continuous moisture.

### PROPER USES OF PUZZOLAN CEMENT.

Puzzolan cement never becomes extremely hard like Portland, but Puzzolan mortars and concretes are tougher or less brittle than Portland.

The cement is well adapted for use in sea water, and generally in all positions where constantly exposed to moisture, such as in foundations of buildings, sewers and drains, and underground works generally, and in the interior of heavy masses of masonry or concrete.

It is unfit for use when subjected to mechanical wear, attrition, or blows. It should never be used where it may be exposed for long periods to dry air, even after it has well set. It will turn white and disintegrate, due to the oxidation of its sulphides at the surface under such exposure.

Specifications for Portland, Natural, and Puzzolan cement are appended hereto.

Respectfully submitted.

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*Major, Corps of Engineers.*
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Brig. Gen. G. L. GILLESPIE,
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### SPECIFICATIONS FOR AMERICAN PORTLAND CEMENT.

(1) The cement shall be an American Portland, dry and free from lumps. By a Portland cement is meant the product obtained from the heating or calcining up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least 1.7 times as much of lime, by weight, as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcination, and thereafter additions or substitutions for the purpose only of regulating certain properties of technical importance to be allowable to not exceeding 2 per cent of the calcined product.

(2) The cement shall be put up in strong, sound barrels well lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labeled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not established itself as a high-grade Portland cement and has not for three years or more given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor:

No cement will be allowed to be used except established brands of high-grade Portland cement which have been made by the same mill and in successful use under similar climatic conditions to those of the proposed work for at least three years.)

(5) The average weight per barrel shall not be less than 375 pounds net. Four sacks shall contain one barrel of cement. If the weight, as determined by test weighings, is found to be below 375 pounds per barrel, the cement may be rejected, or at the option of the engineer officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, specific gravity, soundness, time of setting, and tensile strength of the cement.

(7) *Fineness.*—Ninty-two per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) *Specific Gravity.*—The specific gravity of the cement, as determined from a sample which has been carefully dried, shall be between 3.10 and 3.25.

(9) *Soundness.*—To test the soundness of the cement, at least two pats of neat cement mixed for five minutes with 20 per cent of water by weight shall be made on glass, each pat about 3 inches in diameter and one-half inch thick at the center, tapering thence to a thin edge. The pats are to be kept under a wet cloth until finally set, when one is to be placed in fresh water for twenty-eight days. The second pat will be placed in water which will be raised to the boiling point for six hours, then allowed to cool. Neither should show distortion or cracks.

The boiling test may or may not reject at the option of the engineer officer in charge.

(10) *Time of Setting.*—The cement shall not acquire its initial set in less than forty-five minutes and must have acquired its final set in ten hours.

(The following paragraph will be substituted for the above in case a quick-setting cement is desired:

The cement shall not acquire its initial set in less than twenty nor more than thirty minutes, and must have acquired its final set in not less than forty-five minutes nor in more than two and one-half hours.)

The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to weigh 1 pound.

(11) *Tensile Strength.*—Briquettes made of neat cement, after being kept in air for twenty-four hours under a wet cloth and the balance of the time in water, shall develop tensile strength per square inch as follows:

After seven days, 450 pounds; after twenty-eight days, 540 pounds.

Briquettes made of 1 part cement and 3 parts standard sand, by weight, shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; after twenty-eight days, 220 pounds.

(In case quick-setting cement is desired, the following tensile strengths shall be substituted for the above:

Neat briquettes: After seven days, 400 pounds; after twenty-eight days, 480 pounds.

Briquettes of 1 part cement to 3 parts standard sand: After seven days, 120 pounds; after twenty-eight days, 180 pounds.)

(12) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(13) When making briquettes neat cement will be mixed with 20 per cent of water by weight, and sand and cement with $12\frac{1}{2}$ per cent of water by weight. After being thoroughly mixed and worked for five minutes, the cement or mortar will be placed in the briquette mold in four equal layers, and each layer rammed and compressed by thirty blows of a soft brass or

copper rammer three-quarters of an inch in diameter (or seven-tenths of an inch square, with rounded corners), weighing one pound. It is to be allowed to drop on the mixture from a height of about half an inch. When the ramming has been completed, the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mold.

(14) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subsequent shipments must come up to those found with the sample.

(15) A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer in charge may, if he deem it to the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner herein specified. All expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

## SPECIFICATIONS FOR NATURAL CEMENT.

(1) The cement shall be a freshly-packed natural or Rosendale, dry, and free from lumps. By Natural cement is meant one made by calcining natural rock at a heat below incipient fusion, and grinding the product to powder.

(2) The cement shall be put up in strong, sound barrels, well lined with paper so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labeled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected, or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor:

No cement will be allowed to be used except established brands of high-grade natural cement which have been in successful use under similar climatic conditions to those of the proposed work.)

(5) The average net weight per barrel shall not be less than 300 pounds. (West of the Allegheny Mountains this may be 265 pounds) . . . sacks of cement shall have the same weight as 1 barrel. If the average net weight, as determined by test weighings, is found to be below 300 pounds (265 pounds) per barrel, the cement may be rejected, or, at the option of the engineer officer in charge, the contractor may be required to supply free of cost to the United States an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, time of setting, and tensile strength of the cement.

(7) *Fineness.*—At least 80 per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) *Time of Setting.*—The cement shall not acquire its initial set in less than twenty minutes and must have acquired its final set in four hours.

(9) The time of setting is to be determined from a pat of neat cement mixed for five minutes with 30 per cent of water by weight and kept under a wet cloth until finally set. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to weigh 1 pound.

(10) *Tensile Strength.*—Briquettes made of neat cement shall develop the following tensile strengths per square inch, after having been kept in air for twenty-four hours under a wet cloth and the balance of the time in water:

At the end of seven days, 90 pounds; at the end of twenty-eight days, 200 pounds.

Briquettes made of one part cement and one part standard sands by weight shall develop the following tensile strengths per square inch:

After seven days, 60 pounds; after twenty-eight days, 150 pounds.

(11) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any

cement not showing an increase of strength in the twenty-eight day tests over the seven-day tests will be rejected.

(12) The neat cement for briquettes shall be mixed with 30 per cent of water by weight, and the sand and cement with 17 per cent of water by weight. After being thoroughly mixed and worked for five minutes the cement or mortar is to be placed in the briquette mold in four equal layers, each of which is to be rammed and compressed by thirty blows of a soft brass or copper rammer three-fourths of an inch in diameter (or seven-tenths of an inch square with rounded corners), weighing 1 pound. It is to be allowed to drop on the mixture from a height of about a half an inch. Upon the completion of the ramming the surplus cement shall be struck off and the last layer smoothed with a trowel held nearly horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mold.

(13) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of the bids. Any cement showing by sample, higher tests than those given must maintain the average so shown in subsequent deliveries.

(14) A cement may be rejected which fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer may, if he deems it to the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner above specified. All expenses of such tests shall be paid by the contractor, and all such tests shall be made on samples furnished by the engineer officer from cement acutally delivered to him.

### SPECIFICATIONS FOR PUZZOLAN CEMENT.

(1) The cement shall be a Pozzolan of uniform quality, finely and freshly ground, dry, and free from lumps, made by grinding together without subsequent calcination granulated blast-furnace slag with slaked lime.

(2) The cement shall be put in strong sound barrels well lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labeled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected, or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed, and for any brand from cement works that do not make and test the slag used in the cement.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor:

No cement will be allowed to be used except established brands of high-grade Puzzolan cement which have been in successful use under similar climatic conditions to those of the proposed work and which come from cement works that make the slag used in the cement.)

(5) The average weight per barrel shall not be less than 330 pounds net. Four sacks shall contain 1 barrel of cement. If the weight as determined by test weighings is found to be below 330 pounds per barrel, the cement may be rejected or, at the option of the engineer officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, specific gravity, soundness, time of setting, and tensile strength of the cement.

(7) *Fineness.*—Ninety-seven per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) *Specific Gravity.*—The specific gravity of the cement as determined from a sample which has been carefully dried, shall be between 2.7 and 2.8.

(9) *Soundness.*—To test the soundness of cement, pats of neat cement mixed for five minutes with 18 per cent of water by weight shall be made on glass, each pat about 3 inches in diameter and one-half inch thick at the center, tapering thence to a thin edge. The pats are to be kept under wet cloths until finally set, when they are to be placed in fresh water. They should not show distortion or cracks at the end of twenty-eight days.

(10) *Time of Setting.*—The cement shall not acquire its initial set in less than forty-five minutes and shall acquire its final set in ten hours. The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to one-fourth pound weight. The final set has been acquired when the pat will bear, without being

appreciably indented, a wire one twenty-fourth inch in diameter loaded to 1 pound weight.

(11) *Tensile strength.*—Briquettes made of neat cement, after being kept in air under a wet cloth for twenty-four hours and the balance of the time in water, shall develop tensile strengths per square inch as follows:

After seven days, 350 pounds; after twenty-eight days, 500 pounds.

Briquettes made of one part cement and three parts standard sand by weight shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; after twenty-eight days, 220 pounds.

(12) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(13) When making briquettes neat cement will be mixed with 18 per cent of water by weight, and sand and cement with 10 per cent of water by weight. After being thoroughly mixed and worked for five minutes the cement or mortar will be placed in the briquette mold in four equal layers and each layer rammed and compressed by thirty blows of a soft brass or copper rammer, three-quarters of an inch in diameter or seven-tenths of an inch square, with rounded corners, weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. When the ramming has been completed the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mold.

(14) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subsequent shipments must come up to those found with the sample.

(15) A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires the engineer officer in charge may, if he deems it to the interest of the United States, have any or all of the tests made or repeated at some recognized testing laboratory in the manner herein specified, all expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

# APPENDIX C.

## THE ENGINEER AS AN EXPERT WITNESS AND COUNSEL.*

### DEFINITIONS AND DISTINCTIONS.

*An Expert Witness* is one who is allowed by the court to testify in a case by giving his *opinions* on hypothetical conditions, the basis of which has been established by other witnesses. To qualify as an expert witness one must be able to show such a knowledge of, and familiarity with, the subject, either theoretical or practical or both, as will convince the court that he is competent to give to the court and jury material aid in arriving at a true solution of the problem in hand. An expert witness will not be allowed to testify if, in the opinion of the court, the jury is competent to judge of the evidence and to draw from it correct conclusions. The peculiar function of the expert witness, therefore, is to bring to bear upon the case on trial such scientific or technical knowledge as the average citizen does not possess, and which is necessary to a fair understanding of the significance of the facts which have been established by the testimony of other witnesses. The ordinary witness is not allowed to express *opinions,* his testimony being limited to what he claims to *know,* of his own knowledge. Similarly the expert witness must base his *opinion* of the proper *meaning* of the facts established, on his own knowledge of the subject, and not on second-hand information. The expert witness is expected to be without bias in the case, although he is usually called and paid by one of the parties to the suit. He acts as an interpreter of established facts, explaining their meaning to the jury, and the proper inferences to be drawn from them, just as a language interpreter may be introduced in a trial to explain the meaning of the language used by a witness who testifies in a foreign tongue. In fact the laws and the language of science, and a knowledge of the technical trades is as a foreign language to the average citizen. But just as a language interpreter is expected to truly, to the best of his ability, interpret the language of a foreigner to the jury in a trial, so the jury has a right to expect a person to interpret the facts truly who has been introduced in a suit at law as an expert witness. And just as a language interpreter would be employed by the court, and his compensation made a part of the costs of the case, so the scientific or technical interpreter should be similarly called and paid. Unfortunately this is not the custom in English speaking coun-

*See also, chapters on this subject in the first and third of Wait's works named in preface to 3rd edition.

tries (as it is in Germany and France), and hence the English "expert" is called and paid by one of the parties. This usually necessitates the calling of other "experts" by the other side, and we see the awkward spectacle of two sets of interpreters explaining the meaning of the same set of facts in different ways. Much of this disagreement is natural and inevitable, by the most honest men, as witness the very common disagreement among the members of the same supreme bench, state or national, all being presumably equally competent, and all having heard identically the same testimony. Such disagreement is common also in all the affairs of life, between men who would appear to be equally competent to draw true conclusions from the given evidence. In nearly all cases submitted to experts in law courts, there is considerable latitude for the exercise of the judgment, and one's testimony is likely to be largely influenced by one's previous experience in such matters. The mere fact, therefore, that experts introduced on opposing sides in the trial of cases, should differ in their conclusions, is not necessarily an evidence of bias, or of incompetence, or of dishonesty. In fact they have come to the subject through consultation with the respective attorneys, and these have necessarily seen the problem from opposite points of view. Very naturally, therefore, the experts have been led to see the facts in different relations, and on the stand they may not easily free their minds from these preconceptions, however honestly they are disposed.

*An Expert Counsel* is one who has scientific or technical attainments in the field in question and who is called in to aid the attorneys in the case with his specialized knowledge. Such a person stands towards his principal in the relation of an attorney, or advocate, the same as the legal counsel, and is of necessity a partisan. He is employed to make the most possible out of his employer's case, and it is as legitimate a position for him to take as it is for the lawyer. In England the greatest Civil Engineers have long acted in this capacity in parliamentary legislation, a kind of professional business almost unknown in the United States.

A very large field for this sort of practice for engineers is the growing one of patent litigation. Here engineers and other kinds of scientific and practical men become a necessity to patent lawyers, who cannot be fully informed in all the subjects which come before them.

In general, an expert counsel should not be put upon the witness stand in a court trial. He has deliberately accepted the position of a partisan, and he cannot afford to appear at once as an advocate and as a disinterested interpreter of assumed facts. If he undertakes the task of an advocate, he should refrain from acting also as an unbiased interpreter.

*The Combined Expert Counsel and Witness.* When the expert acts either as witness or as counsel, his duties are clear. It is when he undertakes to combine the two functions that he gets into trouble, and brings odium upon his profession. The problem is not free from inherent difficulties. The expert witness must of necessity confer with his attorneys in advance in order to properly prepare himself for his duties, and he must also, in justice to himself and to his attorneys, come to a clear understanding with them as to the conduct of the case. This often necessitates a considerable coaching of the attorneys by the expert witness, in order that they may come to understand the principles involved sufficiently to bring out the significant facts in the examination of the witnesses of fact, as well as in the examination of the expert witness who is a witness of opinion, based on the facts which have been developed. But this counseling with, and coaching of, the attorneys on one side of the case is pretty sure to develop the expert witness into a partisan himself, and he goes upon the stand thoroughly biased towards the interest of his principal, which he has been unconsciously studying.

Probably the only wise solution of this complicated problem, so long as the experts are employed by the principals, is for the expert to first thoroughly satisfy himself, if possible, by a study of both sides of the case, on which side truth and justice lie, and then to accept service on that side, and do all he can to win out. This, however, it is often impossible to do. He would have to determine in advance the very question which the suit is intended to establish. The whole problem is fraught with difficulties, and will continue to be, until the expert witnesses are appointed by the court and their compensation made a part of the costs of the suit. The parties could still engage their expert counsels, and these would take and consistently hold the attitude of advocates, and would not go on the witness stand. Our whole trouble now arises from the expert being forced, in justice to himself, to become both a counselor and a witness, two positions which are radically opposed to each other.

## REQUISITE QUALIFICATIONS.

The expert witness sets himself up as an instructor of judge and jury upon the particular questions involved. A given case may require the services of many kinds of experts. Any person may be considered an "expert" in those matters with which he has an intimate personal acquaintance, and which are outside the range of the common knowledge of the average intelligent citizen. Thus a lumberman, however limited in his general education, may be an expert concerning the dangers in-

volved in felling trees, hauling and rafting logs, and the like, this sort of knowledge not being common to the ordinary citizen who lives apart from such industries. Such a person would be allowed to express an *opinion* in court on a stated hypothetical case involving these matters, while the most highly trained Civil Engineer, without this practical knowledge, would probably not be able to qualify as an expert witness in such a case. He might reason that his theoretical scientific knowledge would enable him to form a reliable opinion in these matters, but probably no court would admit it.

*Unless one can feel great assurance that the "opinions" he will express have substantially the weight of "facts," he should not offer himself as an expert witness.* A feeling that his opinions are highly probable merely should not embolden him to offer them, except as mere probabilities. If his opinions have, in his mind, the weight of facts, he should be able to give good reasons therefor, and he should fully prepare himself to do so. He should not rely merely on theoretical considerations if it is possible to obtain demonstrated facts, and these facts should have come within the range of his own experience.

RESPONSIBILITIES ASSUMED.

An expert witness assumes very grave responsibilities. If he proves unworthy, either through incompetence, or evident bias, or confusion, or self-contradiction, or by being shown by the opposing side to be clearly in the wrong, he not only brings chagrin and loss of reputation upon himself, but he fatally injures the cause he has tried to help, and he has brought reproach upon his entire profession. It is not a very comfortable business at best, and unless one feels that he is clearly master of the situation he should not accept service in this capacity.

EXPERT WITNESSES IN BAD ODOR.

No good lawyer will employ an expert witness if he can avoid it. He more often employs expert counsel. He well knows that courts and juries are always suspicious of the so-called "experts," and are prejudiced against them. For this reason the expert witness should spare no pains to secure the good opinion of both court and jury from the moment he takes the stand. He should assume and maintain a calm, judicial disinterested attitude; he should answer with great deliberation and caution; should not allow himself to get excited or confused; and he should never resent a provoking attitude and manner of the opposing counsel on the cross-examination. His own counsel should protect him from outrageous treatment, but if he does not the witness may calmly appeal to the judge for such protection. The witness should not try to conceal his

business relations to his principal, but take and hold with dignity the position of one who though engaged by one of the parties to the suit, is competent to assist the judge and jury to arrive at a just verdict in the case on trial, and he should indicate by his manner that this is what he is there for. His answers should be addressed to the jury, looking them in the face, and his explanations should be made to them as though he was instructing them and wished them to get a clear conception of his meaning. This always requires the use of common instead of technical words, and he should judge by their countenances, if possible, whether or not they understand him. A competent expert witness becomes in this way part of the judicial force in the case, putting himself with the judge and jury, rather than with either of the parties to the suit. In this way both judge and jury are won over to see the problem from his point of view, and his evidence will have great weight in determining the case.

### THE OPPOSING EXPERTS.

The expert witness must always anticipate meeting with experts on the other side of the case, and he should anticipate all that they are likely to testify to, and shape his testimony so as to meet these arguments. He may not be recalled to answer such opposing statements, although it is very common to put the expert witness on again in rebuttal, after he has heard the testimony of the opposing witnesses. If the experts on each side are both competent and honest they need not fear any serious disagreement.

### DUTIES OF THE EXPERT WITNESS TO HIS PRINCIPAL.

Since the expert witness is engaged by one of the parties, and is presumably well paid for his time, he can afford to fully prepare himself for his task, and this he should do the same as he would for any other professional service. He will not be allowed to use books or records on the stand, except "to refresh his memory," and to express what he also knows of his own knowledge, though this knowledge (as of mathematics, etc.) may have been originally gained from books. *He may, however, take questions under advisement and agree to answer them at the next session.* This privilege should be embraced whenever the witness cannot answer off-hand or by a short computation. Books may be used, also, for authority for the generally accepted truths of science, if the particular author is regarded as standard. They may be used also in support of what the witness claims to know by experience or practice. This, and all such questions, are however, for the court to determine and the particular circumstances would govern. Only memoranda taken by the witness himself, and at or near the time of the occurrence, can be introduced as evidence, or used to refresh

the memory, and then the witness must be ready to swear to the correctness of the record. Statements may not be read from books to the witness by his counsel for his approval or denial, but statements made by the witness on a former trial may be so read to him.

The expert witness should reinforce his testimony with maps, charts, models, photographs, and the like if by so doing he can make more clear his views of the case. Photographs are often an invaluable aid in court trials. The camera tells no lies, and it is a cheap and perfect kind of evidence whenever it will serve a purpose. All such aids should have been made by the witness or under his direction, so that he can swear to their correctness.

### DUTIES OF AN EXPERT TO HIS ATTORNEY.

The expert witness should see to it that his attorney obtains in advance a clear comprehension of his view of the case, so that he may bring out by proper questions the essential facts and opinions. This will often require considerable coaching of the attorney by the witness, even when he is trying to act as a purely disinterested party, and in a judicial capacity.

### DUTIES OF THE EXPERT WITNESS TO HIMSELF.

In this business the expert witness owes his highest duty to himself and to his profession. Here is where he is most likely to fall short. He must try to see both sides of the case, and not to overstate the truth as he sees it, which is usually only another name for the highest probability. Neither should he state probabilities as absolute truths. Moderation of statement will usually have greater weight with both judge and jury than more absolute and dogmatic statements. What the jury finally arrive at is at best only a high probability, and this is all they are looking for. The witness' duty to himself, therefore, may be summed up in a *thorough preparation for the case* and in *moderation of statement* when on the stand.

### COMPENSATION.

Because of the great responsibilities one assumes in becoming an expert witness he should be well paid. If he is competent to serve as an expert witness in a scientific way, his time is valuable.

All the time required in preparation should be charged up, in addition to the time spent on the trial. It is customary to charge a retaining fee, the size of which would be in proportion to the importance of the interests involved, and a *per diem* for all time spent on the case, and expenses for attendance at court, and for any diagrams, models, etc., which had been prepared. A definite agreement on these matters should be entered into in advance, and the retaining fee is commonly paid in advance.

# APPENDIX D.*

## *STANDARD SPECIFICATIONS FOR STEEL AND WROUGHT IRON*

PROPOSED BY THE AMERICAN SECTION OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

### I. STRUCTURAL STEEL FOR BRIDGES AND SHIPS.

PROCESS OF MANUFACTURE.

1. Steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES.

2. Each of the three classes of structural steel for bridges and ships shall conform to the following limits in chemical composition:

| | Steel made by the acid process. Per cent | Steel made by the basic process. Per cent |
|---|---|---|
| Phosphorus shall not exceed .................... | 0.08 | 0.06 |
| Sulphur shall not exceed ....................... | 0.06 | 0.06 |

PHYSICAL PROPERTIES.

3. **Classes.**—There shall be three classes of structural steel for bridges and ships, namely: RIVET-STEEL, SOFT STEEL, and MEDIUM STEEL, which shall conform to the following physical qualities:

4. **Tensile Tests.**—

| | Rivet-steel. | Soft Steel | Medium Steel. |
|---|---|---|---|
| Tensile strength, pounds per square inch ............. | 50,000 to 60,000 | 52,000 to 62,000 | 60,000 to 70,000 |
| Yield point in pounds per square inch, shall not be less than....... ....... | 1/2 T. S. | 1/2 T. S. | 1/2 T. S. |
| Elongation per cent in eight inches shall not be less than........ .......... | 26 | 25 | 22 |

5. **Modifications in Elongation for Thin and Thick Material.**—For material less than five-sixteenths inch (5/16″), and more than three-fourths inch (3/4″) in thickness, the following modifications shall be made in the requirements for elongation:

(*a*) For each increase of one-eighth inch (1/8″) in thickness above three-fourths inch (3/4″), a deduction of one per cent (1%) shall be made from the specified elongation.

(*b*) For each decrease of one-sixteenth inch (1/16″) in thickness below five-sixteenths inch (5/16″), a deduction of two and one-half per cent (2½%) shall be made from the specified elongation.

(*c*) For pins made from any of the three classes of steel, the required elongation shall be five per cent (5%) less than that specified in paragraph No. 4, as determined on a test specimen, the centre of which shall be one (1″) from the surface.

6. **Tensile Tests of Eyebars.**—Eyebars shall be of medium steel. Full-sized tests shall show 12½ per cent elongation in fifteen feet of the body of the eyebar, and the tensile strength shall not be less than 55,000 pounds per square inch. Eye-

*This appendix reprinted from the author's *Materials of Construction*.

bars shall be required to break in the body, but should an eyebar break in the head, and show twelve and one-half per cent (12½%) elongation in fifteen feet and the tensile strength specified, it shall not be cause for rejection, provided that not more than one-third (1/3) of the total number of eyebars tested break in the head.

7. **Bending Tests.**—The three classes of structural steel for bridges and ships shall conform to the following bending tests ; and for this purpose the test specimen shall be one and one-half inches wide, if possible, and for all material three-fourths inch (3/4″) or less in thickness the test specimen shall be of the same thickness as that of the finished material from which it is cut, but for material more than three-fourths inch (3/4″) thick the bending-test specimen may be one-half inch (1/2″) thick.

Rivet-rounds shall be tested of full size as rolled.

(*d*) Rivet-steel shall bend cold 180° flat on itself without fracture on the outside of the bent portion.

(*e*) Soft steel shall bend cold 180° flat on itself without fracture on the outside of the bent portion.

(*f*) Medium steel shall bend cold 180° around a diameter equal to the thickness of the specimen tested, without fracture on the outside of the bent portion.

TEST PIECES AND METHODS OF TESTING.

8. **Test Specimen for Tensile Test.**—The standard test specimen of eight-inch (8″) gauged length, shall be used to determine the physical properties specified in

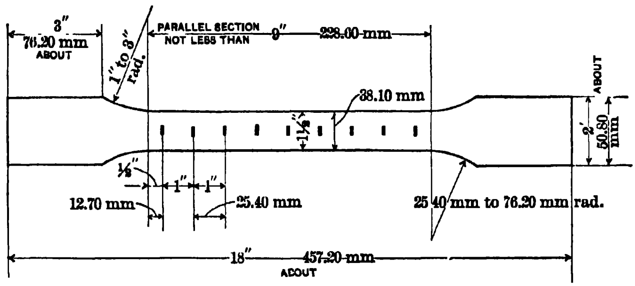


FIG. 638.—STANDARD FORM OF TENSION-TEST SPECIMEN.

paragraphs No. 4 and 5. The standard shape of the test specimen for sheared plates shall be as shown in Fig. 638.

LONG FORM OF STANDARD TENSION-TEST SPECIMEN.

For other material the test specimen may be the same as for sheared plates, or it may be planed or turned parallel throughout its entire length, and, in all cases where possible, two opposite sides of the test specimens shall be the rolled surfaces. Rivet-rounds and small rolled bars shall be tested of full size as rolled.

9. **Number of Tensile Tests.**—One tensile-test specimen shall be taken from the finished material of each melt; but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

10. **Test Specimens for Bending.**—One test specimen for bending shall be taken from the finished material of each melt as it comes from the rolls, and for material three-fourths inch (3/4″) and less in thickness this specimen shall have the natural rolled surface on two opposite sides. The bending-test specimen shall be one and one-half inches (1½″) wide, if possible, and for material more than three-fourths inch (3/4″) thick the bending-test specimen may be one-half inch (1/2″) thick. The sheared edges of bending-test specimens may be milled or planed.

(*g*) The bending test may be made by pressure or by blows.

11. **Annealed Test Specimens.**—Material which is to be used without annealing

or further treatment shall be tested for tensile strength in the condition in which it comes from the rolls. Where it is impracticable to secure a test specimen from material which has been annealed or otherwise treated, a full-sized section of tensile-test specimen length shall be similarly treated before cutting the tensile-test specimen therefrom.

12. **Yield-point.**—For the purpose of this specification, the yield-point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

13. **Sample for Chemical Analysis.**—In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot.

VARIATION IN WEIGHT.

14. The variation in cross-section or weight of more than 2½ per cent from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(*h*) Plates 12½ pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than 2½ per cent variation above or 2½ per cent below the theoretical weight. When 100 inches wide and over, 5 per cent above or 5 per cent below the theoretical weight.

(*i*) Plates under 12½ pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, 2½ per cent above or 2½ per cent below the theoretical weight. 75 inches wide up to 100 inches wide, 5 per cent above or 3 per cent below the theoretical weight. When 100 inches wide and over, 10 per cent above or 3 per cent below the theoretical weight.

*   *   *   *   *   *   *   *   *   *

(*j*) For all plates ordered to gauge there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over 1/100 inch less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

*Plates 1/4 inch and over in thickness.*

| Thickness of Plate Inch. | Width of Plate. Up to 75 inches. Per cent. | 75 to 100 inches. Per cent. | Over 100 inches. Per cent. |
|---|---|---|---|
| 1/4 | 10 | 14 | 18 |
| 5/16 | 8 | 12 | 16 |
| 3/8 | 7 | 10 | 13 |
| 7/16 | 6 | 8 | 10 |
| 1/2 | 5 | 7 | 9 |
| 9/16 | 4½ | 6½ | 8½ |
| 5/8 | 4 | 6 | 8 |
| Over 5/8 | 3½ | 5 | 6½ |

*Plates under 1/4 inch in thickness.*

| Thickness of Plate. Inch. | Width of Plate. Up to 50 inches. Per cent. | 50 inches and above. Per cent. |
|---|---|---|
| 1/8 up to 5/32 | 10 | 15 |
| 5/32 " 3/16 | 8½ | 12½ |
| 3/16 " 1/4 | 7 | 10 |

FINISH.

15. **Finished material must be free from injurious seams, flaws or cracks, and have a workmanlike finish.**

BRANDING.

16. Every finished piece of steel shall be stamped with the melt number, and steel for pins shall have the melt number stamped on the ends. Rivets and lacing-steel, and small pieces for pin-plates and stiffeners, may be shipped in bundles, securely wired together, with the melt number on a metal tag attached.

INSPECTION.

17. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

## II. STRUCTURAL STEEL FOR BUILDINGS.

PROCESS OF MANUFACTURE.

1. Steel may be made by either the open-hearth or Bessemer process.

CHEMICAL PROPERTIES.

2. Each of the two classes of structural steel for buildings shall not contain more than 0.1 per cent of phosphorus.

PHYSICAL PROPERTIES.

3. **Classes.**—There shall be two classes of structural steel for buildings, namely, RIVET-STEEL and MEDIUM STEEL, which shall conform to the following physical qualities:

4. **Tensile Tests.**—

| | Rivet-steel | Medium Steel. |
|---|---|---|
| Tensile strength, pounds per square inch............ | 50,000 to 60,000 | 60,000 to 70,000 |
| Yield-point, in pounds per square inch, shall not be less than.................................... | 1/2 T. S. | 1/2 T. S. |
| Elongation, per cent, in eight inches shall not be less than.......................................... | 26 | 22 |

5. **Modifications in Elongation for Thin and Thick Material.**—For material less than five-sixteenths inch (5/16") and more than three-fourths inch (3/4") in thickness the following modifications shall be made in the requirements for elongation:

(*a*) For each increase of one-eighth inch (1/8") in thickness above three-fourths inch (3/4") a deduction of one per cent (1%) shall be made from the specified elongation.

(*b*) For each decrease of one-sixteenth inch (1/16") in thickness below five-sixteenths inch (5/16") a deduction of two and one-half per cent (2½%) shall be made from the specified elongation.

(*c*) For pins the required elongation shall be five per cent (5%) less than that specified in paragraph No. 4, as determined on a test specimen the centre of which shall be one inch (1") from the surface.

6. **Bending Tests.**—The two classes of structural steel for buildings shall conform to the following bending tests; and for this purpose the test specimen shall be one and one-half inches (1½") wide, if possible, and for all material three-fourths inch (3/4") or less in thickness the test specimen shall be of the same thickness as that of the finished material from which it is cut, but for material more than three-fourths inch (3/4") thick the bending-test specimen may be one-half inch (1/2") thick:

Rivet-rounds shall be tested of full size as rolled.

(*d*) Rivet-steel shall bend cold 180° flat on itself without fracture on the outside of the bent portion.

(*e*) Medium steel shall bend cold 180° around a diameter equal to the thickness of the specimen tested, without fracture on the outside of the bent portion.

TEST PIECES AND METHODS OF TESTING.

7. **Test Specimen for Tensile Test.**—The standard test specimen of eight-inch (8") gauged length shall be used to determine the physical properties specified in

paragraphs Nos. 4 and 5. The standard shape of the sheared plates shall be as shown in Fig. 688.

For other material the test specimen may be the same as for sheared plates, or it may be planed or turned parallel throughout its entire length, and in all cases where possible two opposite sides of the test specimen shall be the rolled surfaces. Rivet-rounds and small rolled bars shall be tested of full size as rolled.

8. **Number of Tensile Tests.**—One tensile-test specimen shall be taken from the finished material of each melt or blow, but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

9. **Test Specimen for Bending.**—One test specimen for bending shall be taken from the finished material of each melt or blow as it comes from the rolls and for material three-fourths inch (3/4″) and less in thickness this specimen shall have the natural rolled surface on two opposite sides. The bending-test specimen shall be one and one-half inches ($1\frac{1}{2}$″) wide, if possible, and for material more than three-fourths inch (3/4″) thick the bending-test specimen may be one-half inch (1/2″) thick. The sheared edges of bending-test specimens may be milled or planed.

Rivet-rounds shall be tested of full size as rolled.

(*f*) The bending test may be made by pressure or by blows.

10. **Annealed-test Specimens.**—Material which is to be used without annealing or further treatment shall be tested for tensile strength in the condition in which it comes from the rolls. Where it is impracticable to secure a test specimen from material which has been annealed or otherwise treated, a full-sized section of tensile-test specimen length shall be similarly treated before cutting the tensile-test specimen therefrom.

11. **Yield-point.**—For the purposes of this specification the yield-point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

12. **Sample for Chemical Analysis.**—In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot.

VARIATION IN WEIGHT.

13. The variation in cross-section or weight of more than $2\frac{1}{2}$ per cent from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(*g*) Plates $12\frac{1}{2}$ pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than $2\frac{1}{2}$ per cent variation above or $2\frac{1}{2}$ per cent below the theoretical weight. When 100 inches wide and over, 5 per cent above or 5 per cent below the theoretical weight.

(*h*) Plates under $12\frac{1}{2}$ pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, $2\frac{1}{2}$ per cent above or $2\frac{1}{2}$ per cent below the theoretical weight. 75 inches wide up to 100 inches wide, 5 per cent above or 3 per cent below the theoretical weight. When 100 inches wide and over, 10 per cent above or 3 per cent below the theoretical weight.

* * * * * * * * * *

(*i*) For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the table on p. 549.

FINISH.

14. Finished material must be free from injurious seams, flaws or cracks, and have a workmanlike finish.

BRANDING.

15. Every finished piece of steel shall be stamped with the melt or blow number, except that small pieces may be shipped in bundles securely wired together with the melt or blow number on a metal tag attached.

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over 1/100 inch less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

*Plates 1/4 inch and over in thickness.*

| Thickness of Plate. Inch | Width of Plate. Up to 75 inches. Per cent. | 75 to 100 inches. Per cent. | Over 100 inches. Per cent. |
|---|---|---|---|
| 1/4 | 10 | 14 | 18 |
| 5/16 | 8 | 12 | 16 |
| 3/8 | 7 | 10 | 13 |
| 7/16 | 6 | 8 | 10 |
| 1/2 | 5 | 7 | 9 |
| 9/16 | 4½ | 6½ | 8½ |
| 5/8 | 4 | 6 | 8 |
| over 5/8 | 3½ | 5 | 6½ |

*Plates under 1/4 inch in thickness.*

| Thickness of Plate. Inch. | Width of Plate. Up to 50 inches. Per cent | 50 inches and above. Per cent. |
|---|---|---|
| 1/8 up to 5/32 | 10 | 15 |
| 5/32 " 3/16 | 8½ | 12½ |
| 3/16 " 1/4 | 7 | 10 |

INSPECTION.

16. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

## III. OPEN-HEARTH BOILER-PLATE AND RIVET-STEEL.

PROCESS OF MANUFACTURE.

1. Steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES.

2. There shall be three classes of open-hearth boiler-plate and rivet-steel; namely: FLANGE- OR BOILER-STEEL, FIRE-BOX STEEL, and EXTRA-SOFT STEEL, which shall conform to the following limits in chemical composition:

| | Flange- or Boiler-steel. Per cent. | Fire-box Steel. Per cent. | Extra-soft Steel. Per cent. |
|---|---|---|---|
| Phosphorus shall not exceed.. | Acid, 0.06<br>Basic, 0.04 | Acid, 0.04<br>Basic, 0.03 | 0.04 |
| Sulphur shall not exceed .... | 0.05 | 0.04 | 0.04 |
| Manganese ................ | 0.30 to 0.60 | 0.30 to 0.50 | 0.30 to 0.50 |

3. **Boiler-rivet Steel.**—Steel for boiler rivets shall be of the EXTRA-SOFT class, as specified in paragraphs Nos. 2 and 4.

PHYSICAL PROPERTIES.

4. **Tensile Tests.**—The three classes of open-hearth boiler-plate and rivet-steel, namely, FLANGE- OR BOILER-STEEL, FIRE-BOX STEEL, and EXTRA-SOFT STEEL, shall conform to the physical qualities:

| | Flange- or Boiler-steel. | Fire-box Steel. | Extra-soft Steel. |
|---|---|---|---|
| Tensile strength, pounds per square inch ............... | 55,000 to 65,000 | 52,000 to 62,000 | 45,000 to 55,000 |
| Yield-point, in pounds per square inch, shall not be less than. ............. ... | 1/2 T. S. | 1/2 T. S. | 1/2 T. S. |
| Elongation, per cent in eight inches, shall not be less than | 25 | 26 | 28 |

5. **Modifications in Elongation for Thin and Thick Material.**—For material less than five-sixteenths inch (5/16") and more than three-fourths inch (3/4") the following modifications shall be made in the requirements for elongation:

(*a*) For each increase of one-eighth inch (1/8"), in thickness above three-fourths inch (3/4"), a deduction of one per cent (1%) shall be made from the specified elongation.

(*b*) For each decrease of one-sixteenth inch (1/16"), in thickness below five-sixteenths inch (5/16"), a deduction of two and one-half per cent (2½%) shall be made from the specified elongation.

6. **Bending Tests.**—The three classes of open-hearth boiler-plate and rivet-steel shall conform to the following tests, and for this purpose the test specimen shall be one and one-half inches (1½") wide, if possible, and for all material three-fourths inch (3/4") or less in thickness the test specimen shall be of the same thickness as that of the finished material from which it is cut; but for material more than three-fourths inch (3/4") thick, the bending-test specimen may be one-half inch (1/2") thick.

Rivet-rounds shall be tested of full size as rolled.

(*c*) Test specimens cut from the rolled material, as specified above, shall be subjected to a cold-bending test, and also to a quenched-bending test. The cold-bending test shall be made on the material in the condition in which it is to be used, and prior to the quenched-bending test the specimen shall be heated to a light cherry-red, as seen in the dark and quenched in water, the temperature of which is between 80° and 90° Fahrenheit.

(*d*) Flange- or boiler-steel, fire-box steel and rivet-steel, both before and after quenching, shall bend cold one hundred and eighty degrees (180°) flat on itself without fracture on the outside of the bent portion.

7. **Homogeneity Tests.**—For fire-box steel a sample taken from a broken tensile-test specimen shall not show any single seam or cavity more than one-fourth inch (1/4") long in either of three fractures obtained on the test for homogeneity, as described below in paragraph 12.

TESTS PIECES AND METHODS OF TESTING.

8. **Test Specimen for Tensile Test.**—The standard test specimen of eight-inch (8"), gauged length, shall be used to determine the physical properties specified in paragraphs Nos. 4 and 5. The standard shape of the test specimen for sheared plates shall be as shown in Fig. 638.

For other material the test specimen may be the same as for sheared plates, or it may be planed or turned parallel throughout its entire length, and in all cases where possible two opposite sides of the test specimens shall be the rolled surfaces. Rivet-rounds and small rolled bars shall be tested of full size as rolled.

9. **Number of Tensile Tests.**—One tensile-test specimen shall be furnished from each plate as it is rolled, and two tensile-test specimens will be furnished from each melt of rivet-rounds. In case any one of these develops flaws or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

10. **Test Specimens for Bending.**—For material three-fourths inch (3/4") or less in thickness, the bending-test specimen shall have the natural rolled surface on two opposite sides. The bending-test specimens cut from plates shall be one and one-half inches (1½") wide, and for material more than three-fourths inch thick the bending-test specimens may be one-half inch (1/2") thick. The sheared edges of bending-test specimens may be milled or planed. The bending-test specimens for rivet-rounds shall be of full size as rolled. The bending test may be made by pressure or by blows.

11. **Number of Bending Tests.**—One cold-bending specimen and one quenched-bending specimen will be furnished from each plate as it is rolled. Two cold-bending specimens and two quenched-bending specimens will be furnished from each melt of rivet-rounds. The homogeneity test for fire-box steel shall be made on one of the broken tensile specimens.

12. **Homogeneity Tests for Fire-box Steel.**—The homogeneity test for fire-box steel is made as follows: A portion of the broken tensile-test specimen is either

nicked with a chisel or grooved on a machine, transversely about a sixteenth of an inch (1/16″) deep in three places about two inches (2″) apart. The first groove should be made on one side, two inches (2″) from the square end of the specimen; the second, two inches (2″) from it on the opposite side; and the third, two inches (2″) from the last and on the opposite side from it. The test specimen is then put in a vise, with the first groove about a quarter of an inch (1/4″) above the jaws, care being taken to hold it firmly. The projecting end of the test specimen is then broken off by means of a hammer, a number of light blows being used, and the bending being away from the groove. The specimen is broken at the other two grooves in the same way. The object of this treatment is to open and render visible to the eye any seams due to failure to weld up, or to foreign interposed matter, or cavities due to gas-bubbles in the ingot. After rupture one side of each fracture is examined, a pocket lens being used if necessary, and the length of the seams and cavities is determined.

13. **Yield-point.**—For the purpose of this specification the yield-point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

14. **Sample for Chemical Analysis.**—In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot. An additional check analysis may be made from a tensile specimen of each melt used on an order other than in locomotive fire-box steel. In the case of locomotive fire-box steel a check analysis may be made from the tensile specimen from each plate as rolled.

VARIATION IN WEIGHT.

15. The variation in cross-section or weight of more than 2½ per cent from that specified will be of sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(e) Plates, 12½ pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than 2½ per cent variation above or 2½ per cent below the theoretical weight. When 100 inches wide and over, 5 per cent above or 5 per cent below or the theoretical weight.

(f) Plates under 12½ pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, 2½ per cent above or 2½ per cent below the theoretical weight; 75 inches wide up to 100 inches wide, 5 per cent above or 3 per cent below the theoretical weight. When 100 inches wide and over, 10 per cent above or 3 per cent below the theoretical weight.

* * * * * * * * * * *

(g) For all plates ordered to gauge there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over 1/100 inch less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

*Plates 1/4 inch and over in thickness.*

| | Width of Plate. | | |
|---|---|---|---|
| Thickness of Plate. Inch. | Up to 75 inches. Per cent. | 75 to 100 inches. Per cent. | Over 100 inches. Per cent. |
| 1/4 | 10 | 14 | 18 |
| 5/16 | 8 | 12 | 16 |
| 3/8 | 7 | 10 | 18 |
| 7/16 | 6 | 8 | 10 |
| 1/2 | 5 | 7 | 9 |
| 9/16 | 4½ | 6½ | 8½ |
| 5/8 | 4 | 6 | 8 |
| Over 5/8 | 3½ | 5 | 6½ |

*Plates under 1/4 inch in thickness.*

| Thickness of Plate. Inch. | Width of Plate. Up to 50 inches. Per cent. | 50 inches and above. Per cent. |
|---|---|---|
| 1/8 up to 5/32 | 10 | 15 |
| 5/32 " 3/16 | 8½ | 12½ |
| 3/16 " 1/4 | 7 | 10 |

FINISH.

16. All finished material shall be free from injurious surface defects and laminations, and must have a workmanlike finish.

BRANDING.

17. Every finished piece of steel shall be stamped with the melt number, and each plate, and the coupon or test specimen cut from it, shall be stamped with a separate identifying mark or number. Rivet-steel may be shipped in bundles, securely wired together, with the melt number on a metal tag attached.

INSPECTION.

18. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with the specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

## IV. STEEL RAILS.

PROCESS OF MANUFACTURE.

1. (*a*) Steel may be made by the Bessemer or open-hearth process.

(*b*) The entire process of manufacture and testing shall be in accordance with the best standard current practice, and special care shall be taken to conform to the following instructions.

(*c*) Ingots shall be kept in a vertical position in pit-heating furnaces.

(*d*) No bled ingots shall be used.

(*e*) Sufficient material shall be discarded from the top of the ingots to insure sound rails.

CHEMICAL PROPERTIES.

2. Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

| | 50 to 59 + pounds Per cent. | 60 to 69 + pounds. Per cent. | 70 to 79 + pounds. Per cent. | 80 to 89 + pounds. Per cent. | 90 to 100 pounds. Per cent. |
|---|---|---|---|---|---|
| Carbon.................... | 0.35–0 45 | 0.38–0 48 | 0.40–0.50 | 0.43–0.53 | 0.45–0.55 |
| Phosphorus shall not exceed | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Silicon shall not exceed.. .. | 0.20 | 0.20 | 0 20 | 0.20 | 0.20 |
| Manganese.... ........... | 0.70–1.00 | 0.70–1 00 | 0.75–1.05 | 0.80–1.10 | 0.80–1.10 |

PHYSICAL PROPERTIES.

3. **Drop Test.** One drop test shall be made on a piece of rail not more than six feet long, selected from every fifth blow of steel. The rail shall be placed head upwards on the supports, and the various sections shall be subjected to the following impact tests:

| Weight of Rail Pounds per yard. | Height of Drop. Feet. |
|---|---|
| 45 to and including 55 | 15 |
| More than 55 " 65 | 16 |
| " 65 " 75 | 17 |
| " 75 " 85 | 18 |
| " 85 " 100 | 19 |

If any rail break when subjected to the drop test, two additional tests will be made of other rails from the same blow of steel; and if either of these latter tests fail, all the rails of the blow which they represent will be rejected; but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted. If the rails from the tested blow shall be rejected for failure to meet the requirements of the drop test as above specified, two other rails will be subjected to the same tests, one from the blow next preceding, and one from the blow next succeeding the rejected blow. In case the first test taken from the preceding or succeeding blow shall fail, two additional tests shall be taken from the same blow of steel, the acceptance or rejection of which shall also be determined as specified above, and if the rails of the preceding or succeeding blow shall be rejected, similar tests may be taken from the previous or following blows, as the case may be, until the entire group of five blows is tested, if necessary.

The acceptance or rejection of all the rails from any blow will depend upon the result of the tests thereof.

TEST PIECES AND METHODS OF TESTING.

4. **Drop-testing Machine.**—The drop-test machine shall have a tup of two thousand (20000) pounds weight, the striking face of which shall have a radius of not more than five inches (5″), and the test rail shall be placed head upwards on solid supports three feet (3′) apart. The anvil-block shall weigh at least twenty thousand (20,000) pounds, and the supports shall be a part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the tests were made.

5. **Sample for Chemical Analysis.**—The manufacturer shall furnish the inspector, daily, with carbon determinations of each blow, and a complete chemical analysis every twenty-four hours representing the average of the other elements contained in the steel. These analyses shall be made on drillings taken from a small test ingot.

FINISH.

6. **Section.**—Unless otherwise specified, the section of rail shall be the American Standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with paragraph No. 7, relative to specified weight. A variation in height of one sixty-fourth of an inch (1/64″) less and one thirty-second of an inch (1/32″) greater than the specified height will be permitted. A perfect fit of the splice-bars, however, shall be maintained at all times.

7. **Weight.**—The weight of the rails shall be maintained as nearly as possible, after complying with paragraph No. 6, to that specified in contract. A variation of one-half of one per cent (1/2%) for an entire order will be allowed. Rails shall be accepted and paid for according to actual weights.

8. **Length.**—The standard length of rails shall be thirty feet (30′). Ten per cent (10%) of the entire order will be accepted in shorter lengths, varying by even feet down to twenty-four feet (24′). A variation of one-fourth of an inch (1/4″) in length from that specified will be allowed.

9. **Drilling.**—Circular holes for splice-bars shall be drilled in accordance with the specifications of the purchaser. The holes shall accurately conform to the drawing and dimensions furnished in every respect, and must be free from burrs.

10. **Finish.**—Rails shall be straightened while cold, smooth on head, sawed square at ends, and, prior to shipment, shall have the burr occasioned by the saw cutting removed, and the ends made clean. Number 1 rails shall be free from injurious defects and flaws of all kinds.

BRANDING.

11. The name of the maker, the month and the year of manufacture, shall be rolled in raised letters on the side of the web, and the number of the blow shall be stamped on each rail.

INSPECTION.

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is

furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

NO. 2 RAILS.

13. Rails that possess any injurious physical defects, or which for any other cause are not suitable for first-quality, or number 1 rails, shall be considered as number 2 rails, provided, however, that rails which contain any physical defects which seriously impair their strength shall be rejected. The ends of all number 2 rails shall be painted in order to distinguish them.

## V. STEEL SPLICE-BARS.

PROCESS OF MANUFACTURE.

1. Steel for splice-bars may be made by the Bessemer or open-hearth process.

CHEMICAL PROPERTIES.

2. Steel for splice-bars shall conform to the following limits in chemical composition:

| | Per cent. |
|---|---|
| Carbon shall not exceed | 0.15 |
| Phosphorus shall not exceed | 0.10 |
| Manganese | 0.30 to 0.60 |

PHYSICAL PROPERTIES.

3. **Tensile Tests.**—Splice-bar steel shall conform to the following physical qualities:

| | |
|---|---|
| Tensile strength, pounds per square inch | 54,000 to 64,000 |
| Yield-point, pounds per square inch | 32,000 |
| Elongation, per cent, in eight inches shall not be less than | 25 |

4. **Bending Tests.**—(*a*) A test specimen cut from the head of the splice-bar shall bend 180° flat on itself without fracture on the outside of the bent portion.

(*b*) If preferred the bending test may be made on an unpunched splice-bar, which, if necessary, shall be first flattened, and shall then be bent 180° flat on itself without fracture on the outside of the bent portion.

TEST PIECES AND METHODS OF TESTING.

5. **Test Specimen for Tensile Test.**—A test specimen of eight inches (8″) gauged length, cut from the head of the splice-bar, shall be used to determine the physical properties specified in paragraph No. 3.

6. **Number of Tensile Tests.**—One tensile-test specimen shall be taken from the rolled splice-bars of each blow or melt, but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

7. **Test Specimen for Bending.**—One test specimen cut from the head of the splice-bar shall be taken from a rolled bar of each blow or melt, or if preferred the bending test may be made on an unpunched splice-bar, which, if necessary, shall be flattened before testing. The bending test may be made by pressure or by blows.

8. **Yield-point.**—For the purposes of this specification, the yield-point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

9. **Sample for Chemical Analysis.**—In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot.

FINISH.

10. All splice-bars shall be smoothly rolled and true to templet. The bars shall be sheared accurately to length and free from fins and cracks, and shall perfectly fit the rails for which they are intended. The punching and notching shall

accurately conform in every respect to the drawing and dimensions furnished. A variation in weight of more than $2\frac{1}{2}$ per cent from that specified will be sufficient cause for rejection.

BRANDING.

11. The name of the maker and the year of manufacture shall be rolled in raised letters on the side of the splice-bar.

INSPECTION.

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer, to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

## VI. STEEL AXLES.

PROCESS OF MANUFACTURE.

1. Steel for axles shall be made by the open-hearth process.

CHEMICAL PROPERTIES.

2. There will be three classes of steel axles which shall conform to the following limits in chemical composition:

| | Car, engine-truck, and tender-truck axles. Per cent. | Driving-wheel axles (Carbon steel.) Per cent. | Driving-wheel axles. (Nickel steel.) Per cent. |
|---|---|---|---|
| Phosphorus shall not exceed........ | 0.66 | 0.06 | 0.04 |
| Sulphur " " " ........ | 0.06 | 0.06 | 0.04 |
| Nickel " " " ........ | .... | .... | 3.75 |

PHYSICAL PROPERTIES.

3. **Tensile Tests.**—For car, engine-truck, and tender-truck axles no tensile test shall be required.

4. The minimum physical qualities required in the two classes of driving-wheel axles shall be as follows:

| | Driving-wheel axles. (Carbon Steel) | Driving-wheel axles. (Nickel Steel.) |
|---|---|---|
| Tensile strength, pounds per square inch........ | 80,000 | 80,000 |
| Yield-point, pounds per square inch ............ | 40,000 | 50,000 |
| Elongation, per cent, in two inches.............. | 18 | 25 |
| Contraction of area, per cent.................... | ...... | 45 |

5. **Drop Tests.**—One axle selected from each melt, when tested by the drop test described in paragraph No. 9, shall stand the number of blows at the height specified in the following table without rupture and without exceeding, as the result of the first blow, the deflection given. Any melt failing to meet these requirements will be rejected:

| Diameter of axle at centre. Inches. | Number of blows. | Height of drop. Feet. | Deflection. Inches. |
|---|---|---|---|
| $4\frac{1}{4}$ | 5 | 24 | $8\frac{1}{4}$ |
| $4\frac{3}{8}$ | 5 | 26 | $8\frac{1}{4}$ |
| $4\frac{7}{16}$ | 5 | $28\frac{1}{2}$ | $8\frac{1}{4}$ |
| $4\frac{5}{8}$ | 5 | 31 | 8 |
| $4\frac{3}{4}$ | 5 | 34 | 8 |
| $5\frac{3}{8}$ | 5 | 43 | 7 |
| $5\frac{7}{8}$ | 7 | 43 | $5\frac{1}{2}$ |

6. Carbon-steel and nickel-steel driving-wheel axles shall not be subject to the above drop test.

TEST PIECES AND METHODS OF TESTING.

7. **Test Specimen for Tensile Test.**—The standard turned test specimen, one-half inch (1/2″) diameter and two inches (2″) gauged length, shall be used to deter-

BRANDING.

10. Tires shall be stamped with the maker's brand and number in such a manner that each individual tire may be identified.

INSPECTION.

11. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment.

## VIII. STEEL FORGINGS.

PHYSICAL PROPERTIES.

1. **Tensile Tests.**—The minimum physical qualities required of the different-sized forgings of each class shall be as follows:

| Tensile Strength | Yield-point. | Elongation in 2". | Contraction of Area. | |
|---|---|---|---|---|
| Pounds per Square Inch. | | Per Cent. | | |
| | | | | SOFT STEEL OR LOW CARBON STEEL. |
| 58,000 | 29,000 | 28 | 35 | For solid or hollow forgings, no diameter or thickness of section to exceed 10". |
| | | | | CARBON STEEL NOT ANNEALED. |
| 75,000 | 37,500 | 18 | 30 | For solid or hollow forgings, no diameter or thickness of section to exceed 10". |
| | Elastic Limit. | | | CARBON STEEL ANNEALED. |
| 80,000 | 40,000 | 22 | 35 | For solid or hollow forgings, no diameter or thickness of section to exceed 10". |
| 75,000 | 37,500 | 23 | 35 | For solid forgings, no diameter to exceed 20" or thickness of section 15". |
| 70,000 | 35,000 | 24 | 30 | For solid forgings, over 20" diameter. |
| | | | | CARBON STEEL, OIL TEMPERED. |
| 90,000 | 55,000 | 20 | 45 | For solid or hollow forgings, no diameter or thickness of section to exceed 8". |
| | | | | CARBON STEEL, OIL TEMPERED. |
| 85,000 | 50,000 | 22 | 45 | For solid forgings of rectangular sections not exceeding 6" in thickness or hollow forgings, the walls of which do not exceed 6" in thickness. |
| 80,000 | 45,000 | 23 | 40 | For solid forgings of rectangular sections not exceeding 10" in thickness or hollow forgings, the walls of which do not exceed 10" in thickness. |
| | | | | NICKEL STEEL ANNEALED. |
| 80,000 | 50,000 | 25 | 45 | For solid or hollow forgings, no diameter or thickness of section to exceed 10". |
| 80,000 | 45,000 | 25 | 45 | For solid forgings, no diameter to exceed 20" or thickness of section 15". |
| 80,000 | 45,000 | 24 | 40 | For solid forgings, over 20" diameter. |
| | | | | NICKEL STEEL, OIL TEMPERED. |
| 95,000 | 65,000 | 21 | 50 | For solid or hollow forgings, no diameter or thickness of section to exceed 8". |
| 90,000 | 60,000 | 22 | 50 | For solid forgings of rectangular sections not exceeding 6" in thickness or hollow forgings, the walls of which do not exceed 6" in thickness. |
| 85,000 | 55,000 | 24 | 45 | For solid forgings of rectangular sections not exceeding 10" in thickness or hollow forgings, the walls of which do not exceed 10" in thickness. |

BRANDING.

13. Each axle shall be legibly stamped with the melt number and initials of the maker at the places marked on the print or indicated by the inspector.

INSPECTION.

14. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment.

## VII. STEEL TIRES.

PROCESS OF MANUFACTURE.

1. Steel for tires may be made by either the open-hearth or the crucible process.

CHEMICAL PROPERTIES.

2. There will be three classes of steel tires which shall conform to the following limits in chemical composition:

| | Passenger Engines. Per Cent. | Freight Engine and Car Wheels. Per Cent. | Switching Engines. Per Cent. |
|---|---|---|---|
| Manganese shall not exceed ... | 0.80 | 0.80 | 0.80 |
| Silicon shall not be less than... | 0.20 | 0 20 | 0 20 |
| Phosphorus shall not exceed.... | 0.05 | 0.05 | 0.05 |
| Sulphur shall not exceed....... | 0.05 | 0.05 | 0 05 |

PHYSICAL PROPERTIES.

3. **Tensile Tests.**—The minimum physical qualities required in each of the three classes of steel tires shall be as follows:

| | Passenger Engines | Freight Engine and Car Wheels. | Switching Engines. |
|---|---|---|---|
| Tensile strength, pounds per square inch.......... | 100,000 | 110,000 | 120,000 |
| Elongation, per cent in two inches....... ....... | 12 | 10 | 8 |

4. **Drop Tests.**—In the event of the contract calling for a drop test, a test tire from each melt will be furnished at the purchaser's expense, provided it meets the requirements. This test tire shall stand the drop test described in paragraph No. 7, without breaking or cracking, and shall show a minimum deflection equal to $D^2 \div (40T^2 + 2D)$, the letter $D$ being internal diameter and the letter $T$ thickness of tire at centre of tread.

TEST PIECES AND METHODS ON TESTING.

5. **Test Specimen for Tensile Tests.**—The standard turned test specimen, one-half inch (1/2″) diameter and two inches (2″) gauged length, shall be used to determine the physical properties specified in paragraph No. 3. It is shown in Fig. 639.

6. **Location of Tensile Specimens.**—When the drop specimen is specified, this test specimen shall be cut cold from the tested tire at the point least affected by the drop test. If the diameter of the tire is such that the whole circumference of the tire is seriously affected by the drop test, or if no drop test is required, the test specimen shall be forged from a test ingot cast when pouring the melt, the test ingot receiving, as nearly as possible, the same proportion of reduction as the ingots from which the tires are made.

7. **Drop Test Described.**—The test tire shall be placed vertically under the drop, in a running position, on a solid foundation of at least ten tons in weight and subjected to successive blows from a tup weighing 2240 pounds, falling from increasing heights until the required deflection is obtained.

8. **Sample for Chemical Analysis.**—Turnings from the tensile specimen, or drillings from the small test ingot, or turnings from the tire, if preferred by the inspector, shall be used to determine whether the melt is within the limits of chemical composition specified in paragraph No. 2.

FINISH.

9. All tires shall be free from cracks, flaws, or other injurious imperfections, and shall conform to dimensions shown on drawings furnished by the purchaser.

mine the physical properties specified in paragraph No. 4. It is shown in the following sketch :

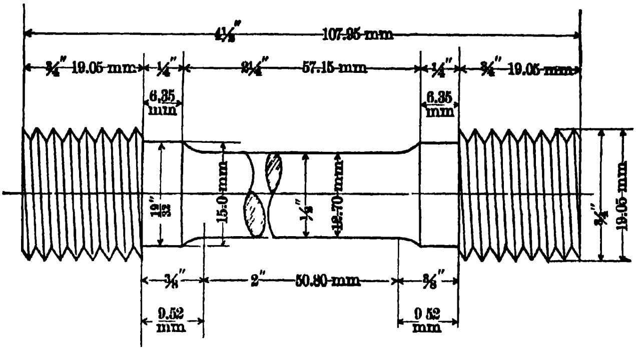


FIG. 639 —SHORT FORM OF STANDARD TENSION-TEST SPECIMEN.

8. **Number and Location of Tensile Specimens.**—For driving axles one longitudinal test specimen shall be cut from one axle of each melt. The centre of this test specimen shall be half-way between the centre and outside of the axle.

9. **Drop Test Described.**—The points of supports on which the axle rests during tests must be three feet apart from centre to centre; the tup must weigh 1640 pounds; the anvil, which is supported on the springs, must weigh 17,500 pounds; it must be free to move in a vertical direction; the springs upon which it rests must be twelve in number, of the kind described on drawing, and the radius of supports and of the striking face on the tup in the direction of the axis of the axle must be five inches (5″). When an axle is tested it must be so placed in the machine that the tup will strike it midway between the ends, and it must be turned over after the first and third blows, and, when required, after the fifth blow. To measure the deflection after the first blow, prepare a straight-edge as long as the axle, by reinforcing it on one side, equally at each end, so that when it is laid on the axle the reinforced parts will rest on the collars or ends of the axle, and the balance of the straight-edge not touch the axle at any place. Next, place the axle in position for test, lay the straight-edge on it, and measure the distance from the straight-edge to the axle, at the middle point of the latter. Then, after the first blow, place the straight-edge on the now bent axle in the same manner as before, and measure the distance from it to that side of the axle next to the straight-edge, at the point farthest away from the latter. The difference between the two measurements is the deflection. The report of the drop test shall state the atmospheric temperature at the time the tests were made.

10. **Yield-point.**—The yield-point specified in paragraph No. 4 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine.

11. **Sample for Chemical Analysis.**—Turnings from the tensile-test specimen of driving axles, or drillings taken midway between the centre and outside of car, engine, and tender-truck axles, or drillings from the same test ingot if preferred by the inspector, shall be used to determine whether the melt is within the limits of chemical composition specified in paragraph No. 2.

FINISH.

12. Axles shall conform in sizes, shapes, and limiting weights to the requirements given on the order or print sent with it. They shall be made and finished in a workmanlike manner, and shall be free from all injurious cracks, seams, or flaws. In centring, sixty- (60-) degree centres must be used, with clearance given at the point to avoid dulling the shop-lathe centres.

PROCESS OF MANUFACTURE.

2. Steel for forgings may be made by the open-hearth, crucible, or Bessemer process.

CHEMICAL PROPERTIES.

3. There will be four classes of steel forgings, which shall conform to the following limits in chemical composition:

| | Forgings of Soft or Low Carbon Steel. Per Cent. | Forgings of Carbon Steel Not Annealed Per Cent. | Forgings of Carbon Steel, Oil-tempered or Annealed Per Cent. | Forgings of Nickel Steel, Oil-tempered or Annealed. Per Cent |
|---|---|---|---|---|
| Phosphorus shall not exceed .... | 0.10 | 0 06 | 0.04 | 0.04 |
| Sulphur " .... | 0 10 | 0.06 | 0 04 | 0.04 |
| Nickel " .... | .... | .... | .... | 3 00–4.00 |

4. **Bending Test.**—A specimen one inch by one-half inch (1" × 1/2") shall bend cold at 180° without fracture on outside of bent portion, as follows:
Around a diameter of 1/2" for forgings of soft steel.
Around a diameter of 1¼" for forgings of carbon steel not annealed.
Around a diameter of 1¼" for forgings of carbon steel annealed, if 20" in diameter or over.
Around a diameter of 1" for forgings of carbon steel annealed, if under 20" diameter.
Around a diameter of 1" for forgings of carbon steel oil-tempered.
Around a diameter of 1/2" for forgings of nickel steel annealed.
Around a diameter of 1" for forgings of nickel steel oil-tempered.

TEST PIECES AND METHODS OF TESTING.

5. **Test Specimen for Tensile Test.**—The standard turned test specimen, one-half inch (1/2") diameter and two inches (2") gauged length, shall be used to determine the physical properties specified in paragraph No. 3. It is shown in Fig. 639.

6. **Number and Location of Tensile Specimens.**—The number and location of test specimens to be taken from a melt, blow, or a forging shall depend upon its character and importance and must therefore be regulated by individual cases. The test specimens shall be cut cold from the forging or full-sized prolongation of same parallel to the axis of the forging and half-way between the centre and outside, the specimens to be longitudinal, i.e., the length of the specimen to correspond with the direction in which the metal is most drawn out or worked. When forgings have large ends or collars, the test specimens shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged or bored, the specimen shall be taken within the finished section prolonged, half-way between the inner and outer surface of the wall of the forging.

7. **Test Specimen for Bending.**—The specimen for bending test one inch by one-half inch (1" × 1/2") shall be cut as specified in paragraph No. 6. The bending test may be made by pressure or by blows.

8. **Yield-point.**—The yield-point specified in paragraph No. 3 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine.

9. **Elastic Limit.**—The elastic limit specified in paragraph No. 3 shall be determined by means of an extensometer, which is to be attached to the test specimen in such manner as to show the change in rate of extension under uniform rate of loading, and will be taken at that point where the proportionality changes.

10. **Sample for Chemical Analysis.**—Turnings from the tensile specimen or drillings from the bending specimen or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in chemical composition specified in paragraph No. 2.

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